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Computer Science and Education

17th International Conference, ICCSE 2022
Ningbo, China, August 18–21, 2022
Revised Selected Papers, Part II

Part 2

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Editors

Computer Science and Education

17th International Conference, ICCSE 2022 Ningbo, China, August 18–21, 2022 Revised Selected Papers, Part II

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Preface

We are pleased to introduce the proceedings of the 17th International Conference on Computer Science and Education (ICCSE 2022), which was held online and offline at NingboTech University in Zhejiang, China, during August 18–21, 2022.

Organized by the China Research Council of Computer Education in Colleges & Universities (CRC-CE) with the technical sponsorship of IEEE Education Society, the conference served as an international forum for presenting state-of-the-art research in the fields of computer science education, engineering, and advanced technology. Focused on rapidly evolving digital literacy and skills, as well as their applications in education practices and digital areas, professors, experts, professionals, and researchers from universities, research institutes, and related industries came together to exchange new research results, ideas, and novel perspectives on a wide range of computer science, especially AI, data science, and engineering, and technology-based education, by addressing frontier technical and business issues essential to the applications of data science in both higher education and advancing e-Society.

We were honored to have three renowned speakers share their latest research works: Ben M. Chen from The Chinese University of Hong Kong, China; Shimin Hu from Tsinghua University, China; and Shihua Li from Southeast University, China. Additionally, ICCSE this year received 510 submissions, of which 168 high-quality manuscripts were accepted in the proceedings. Submissions with the topics of computer science, data science, educational technology, and e-Society or smart society were carefully evaluated through a rigorous double-blind peer-review process (three reviews per submission) by an esteemed panel of international reviewers, comprising the organizing and advisory committee members, as well as other experts in the field from across the world. We express our gratitude to all the authors for their valuable contributions to the conference and their commitment to advancing the field, and to all the reviewers.

Finally, we would like to express gratitude to the program chairs for their wise advice and suggestions on organizing the conference technical program. We are also indebted to the conference organizing committee members, who have all worked extremely hard on the details and activities of this conference.

We sincerely hope that you will find these proceedings instructive and inspiring for further research.

March 2023

Wenxing Hong
Yang Weng

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Contents – Part II

Teaching Innovations in Computer Education Research

Project-Based Learning for 3D Animation Course

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Abstract. 3D animation design is an optional course for some liberal arts majors in our university. Generally, the computer skills of the students in these majors are relatively low. It is hard to understand the concepts of computer animation and master the 3D software application for them. This study demonstrates the experience of using the project-based learning (PBL) method to teach 3D animation design in an evolving program. In the project, students learn 3D animation design with 3ds MAX by completing an architectural tour. The teaching process of PBL is divided into three stages: project assignment, following guidance, and works evaluation. The students involved in the study appreciate the PBL instructional design using an architectural tour for 3D animation course. The PBL method can make students actively engage in learning activities, which are essential for mastering basic concepts, combining theory with practice, and obtaining systematic cognition. The teaching assessment at the end of the semester shows that the PBL method is feasible and effective.

Keywords: Project-based Learning · 3D Animation Design · Architectural Tour

1 Introduction

It is now realized throughout the world that students need to cultivate a wider range of competencies during their formal education than has traditionally been the case [1]. According to [1, 2], the four 21st century competencies are question-solving, collaborative question solving, information technology, and global citizenship. And the educational agenda in schools around the world goes far beyond teaching basic reading, writing, and numeracy. To be more precise, it is the education of thinking [3]. Now more and more universities are clarifying our expectations of education with these universal results. As a result, a number of common optional courses and specialized optional courses are offered to students as part of general education to develop the special skills and abilities that are necessary for them to function in the world of technology.

In our university, 3D animation design is an optional professional course for some majors, such as radio and television, network and new media, and an optional public course for other majors. The teacher usually introduces 3d animation techniques based on 3ds MAX software. The pupils who select the course have to use the computer to build 3D models, give the model materials, and design animation. Hence, the grasp of

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the 3D tool is quite secure for the course. Nevertheless, 3ds MAX is the kind of software that has a complex interface, lots of commands with many parameters, sophisticated operation steps, etc. It requires students to spend enough time and energy learning 3D animation design. Both teachers and novice students consider that it is difficult to learn the course with 3ds MAX. It is also difficult for beginners to learn knowledge and skills over a course of 34 class hours a semester. Furthermore, most of the pupils are from liberal arts majors. Students of these majors have a relatively low level of computer operation generally. It is also hard to understand the concepts of computer graphics and master the 3D software application for them. Therefore, The key issues in teaching are as follows:

- How to overcome the fear of the curriculum of 3D animation design for the students of liberal art?
- How to improve the operational capability of students and encourage them to combine theory with practice?
- How to achieve the teaching objectives of our curriculum, including grasping the basic procedure of 3D animation design and basic operation of 3ds Max, completing and submitting 3D animation works?

It is obvious that a more effective teaching method should be implemented in optional course classes for teaching and learning 3D animation design. Generally speaking, a curriculum is treated cumulatively and fragmentarily, it is not easy to understand. However, project-based work not only lightens the course and encourages a proactive learning attitude, but also does not compromise knowledge and skills [4]. Project-based learning (PBL) is composed of a wide range of instructional strategies in which the project is regarded as a core component [5]. The project lasts for a period of time, varies in complexity and difficulty according to students' ability, and positively involves them in investigative activities, problem-solving, and decision making [6]. Fortunately, PBL can be applied to many various disciplines, where students can benefit from a more practical based learning experience.

In this paper, a project-based approach is described in the 3D animation course with an architectural tour for liberal art students at our university. A model of PBL is proposed and the project implementation is divided into three stages: project assignment, following guidance, and works evaluation. From the perspective of teachers, the study proposes a novel teaching model to help beginners acquire specialized knowledge, skills, and abilities [7]. Teachers use the project to guide students to use their knowledge and abilities, which can finally improve the teaching effect. And students begin to understand the advantages of self-exploration. Data on teaching assessment show that the PBL method can improve teaching quality and learning efficiency.

2 Related Work

The modern teaching methods that focus on practical problems and emphasize students' exploratory exploration of knowledge certainly include project-based teaching. From a historical point of view, it is not a new thing [8]. This educational wisdom originates from John Dewey [9]. John Dewey first advocated learning by doing [10]. Since then, the concept of teaching and learning has been developed by educational researchers into a methodology regarded as "project-based learning". And many studies have shown that the PBL method can replace paper-based, rote, teacher-led classrooms [10].

The PBL pedagogy aims to encourage students to innovate, develop their problem-solving confidence, enhance their communication and management skills, urge them to seek out information on their own, reinforce their awareness of integrating concepts, and enable them to integrate various principles and skills [6]. As far as PBL is concerned, there are many benefits [4, 11], including diversities in all forms [12], and opportunities for developing deep knowledge, skills, and community [13]. Most education researchers believe that project-based learning can provide learning experiences for pupils and help students increase retention rates. Meanwhile, some skills needed to work effectively have been developed.

According to [14], project teaching methods can be classified into three categories. Some projects are completely driven by students' interests without the engagement of the subject of discipline boundaries. In these projects, curriculum standards are not exactly demanded. Teachers focus on student autonomy and collaboration than specific content and skills. Curriculum Integration described by [15], Applied Learning described by [16], and some service learning projects may belong to this kind. Some projects are often created by teachers. These projects are organized around course goals and students have few choices. Students are guided by a topic chosen by the instructor and must meet course requirements upon completion of the project. Many single discipline tasks with prescriptive nature fall into this category. Most projects cannot simply fall into the first category or the second one. They are somewhere in between. So, they are hybrid projects. The reason is that teachers recognize students' autonomy and course goals are equally important. In these projects, students do not choose what they learn, but they have absolute autonomy in how they learn [17].

Despite the difference between these projects, they usually have a similar process. Following [18] who separated PBL into four steps, [19] developed it into six steps, like selecting a project, making plans, activity exploration, making products, sharing results, and making evaluations (see Fig. 1). The phases of a project are not isolated from each other. On the contrary, they are related by influencing each other [20].

It is not enough to teach basic, fragmented knowledge in schools today. Students need a variety of activities to satisfy their interests and gain the necessary abilities and qualities for their future daily jobs [20].

PBL is a student-centered teaching approach designed to develop students' high-level abilities, such as critical thinking, teamwork, project management skills, interdisciplinary skills, and so on [7]. PBL encourages active participation and collaborative learning by creating an authentic situation that students welcome without the constraints of discipline. Therefore, PBL is an effective constructivist teaching model in cultivating the above-mentioned abilities [9] and is widely used in many fields, including STEM education [13, 21], thinking skills [3], biology [5, 22], chemistry[23, 24], information technology [9, 20, 25], engineering [11, 26, 27], etc.

These researches laid the foundation for implementing our teaching strategy of PBL in a 3D animation course. It is crucial to choose a suitable project within the constraints

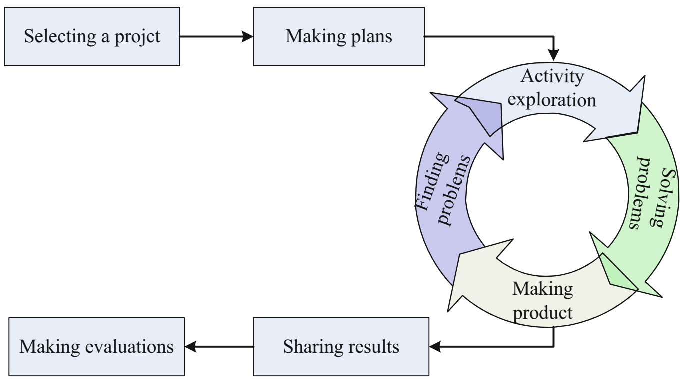

Fig. 1. Phases for implementing PBL

of the environment [9]. And a project usually has some elements, including but not limited to being central to the curriculum [9], focusing on problems, being student-centered, developing project management capacities and interpersonal communication, constructing a concrete artifact, etc. These guidelines are also followed in the section of PBL in 3D animation.

3 PBL in 3D Animation

3.1 3D Animation Course

3D animation design is a public and professional optional curriculum in our university, which is designed to enhance students' comprehensive quality and stretch their minds in a semester, 17 weeks. So, the student population falls into two categories: (a) students whose training programs of their majors, like radio and television, and network and new media, have the course as professional elective course; and (b) students who are from other majors without the course. No matter what kind of students, most of them are pupils of liberal arts in high school.

Generally, 3D animation as computer animation is designed by some computer software, such as 3ds MAX. Hence, the students need computer skills and information literacy, which make them install and use 3ds MAX for the course's practice. Table 1 shows the course content. There are a lot of knowledge points. For instance, three types of copying are Copy, Instance, and Reference. Many methods of the copy are Clone, Mirror, Array, Align, Snapshot, etc. Different modifiers, including Bend, Taper, Twist, FFD, Edit Poly, Lattice, etc., have many different parameters. Additionally, there are lots of materials and textures. All of these contents are new and complex for liberal arts pupils.

Pedagogical approaches that take advantage of isolated examples have been adopted in computer teaching, such as basic modeling, texturing and material application, light and camera, animation, rendering, and more. Teachers give some cases covering different commands or knowledge points to students and choose a few cases to demonstrate. Then students imitate to do them according to the teacher. However, this case-based teaching

Table 1. Outline Of 3d Animation

Topic	Detail
Basic concept	Fundamental of computer animation; the process of animation design
3D Modeling	Basic operation (move, rotate, scale, coordinate system conversion…); build-in primitives (standard primitive, extended primitive, …); modifiers (bend, taper, FFD….); compound objects (proboolean, loft…)
Material and texture	Different material (standard, blend, multi/sub-object, matte/shadow…); different map channel (diffuse color, reflection, refraction, bump, opacity….); different map (bitmap, raytrace, noise, falloff…)
Light and camera	Different lights (standard, photometric); different cameras (target, free, physical)
Animation	Keyframe; track view; controllers
Product output	Render parameters; post-processing

method leads to the fragmentation of knowledge points, which makes it difficult for students to organically link them into a whole and make flexible use of these knowledge points. Then simply offering educators a mixture of face-to-face learning and information technology will not achieve the desired results [28]. Many students complained about the excessive commands, operation steps, and matters that they need to focus on. They cannot remember all of these, not to mention flexible application only through learning in one semester. Students encounter serious difficulties and they are unable to finish a complete works. And the teacher cannot also achieve teaching targets.

Today's students are expected to possess knowledge, skills, and abilities such as critical thinking, problem-solving, innovation, digital literacy, etc. [1, 27]. However, it is impossible to educate students with traditional teaching strategies and methods. Consequently, it is inevitable to adopt other non-traditional teaching approaches for liberal art learners and 3D animation design.

3.2 Model of PBL

As a rule, the term "project" refers to a long-term and product-oriented task or set of tasks [9, 14]. So, the project usually has four properties as Table 2.

In the course on 3D animation design, the teacher employs PBL using an architectural tour to assist students in learning. An architectural tour is a short architectural movie created on a computer, which can supply a realistic environment, diagnose and remedy students' problems, and realize the course goal. It also has the above four characteristics. Generally, the scenes of buildings are on the campus or around. Students are familiar with them and very interested. Furthermore, students can choose a complex or uncomplex architectural scene to complete according to their capacity. So, students are not afraid of the course from the beginning. Figure 2 shows the model of PBL using an architectural tour for learning 3D animation design. The students will experience the three-phase team PBL environment.

Table 2. Properties of Project

Property	Description
Clear learning objectives	Teachers must comprehend the importance and intent of the project. Students must also understand what knowledge to be grasped, what skills to be trained, what competence to be cultivated, and what should be submitted in the end
Complex tasks	The project extends over a significant period and cuts across many disciplines. Students must assign tasks, collect data, analyze data, proceed with implementation, and finally complete the work all by themselves
Division of labor	There is the distribution of roles and distribution of tasks for each student
Outcome	The completion of a project must be reflected in concrete results, which include the design and development of a product, and works presentation for others to use or evaluate

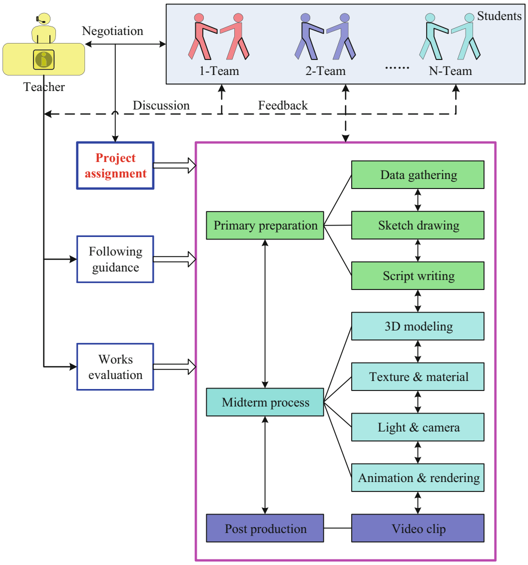

Fig. 2. Model of PBL

As a learning method, the model teaches animation design process and skills in 3ds MAX based on the architectural tour, which is confirmed by negotiation between teacher and students. After the teacher clarifies the course objective and arranged tasks, whole process guidance will be provided to students. For different students, the teacher can also extend the knowledge points. And students will experience the procedure of 3D animation design, including data gathering, sketch drawing, scriptwriting, 3D modeling, textures and materials, light and camera, animation and rendering, and video clips. The concrete implementation of PBL is shown in the next section.

3.3 Implementation of PBL

The PBL is implemented in three stages, including project assignment, following guidance, and works evaluation. There are some specific teaching activities in each phase.

Project Assignment at the beginning of the project, students should know teaching contents, teaching methods, and teaching targets. therefore, the teacher usually briefs the course and the project, especially telling students what to learn, how to learn, where to get it, and how to grade at last, along with expectations.

The mind map of the course is given in Fig. 3, which is similar to Table I. In light of it, students know what they need to master and can study more efficiently. They even learn in advance by watching videos or reading books, if their project is progressing rapidly. After the course overview, the students in one class are formed into groups freely and three to five students per group work well generally.

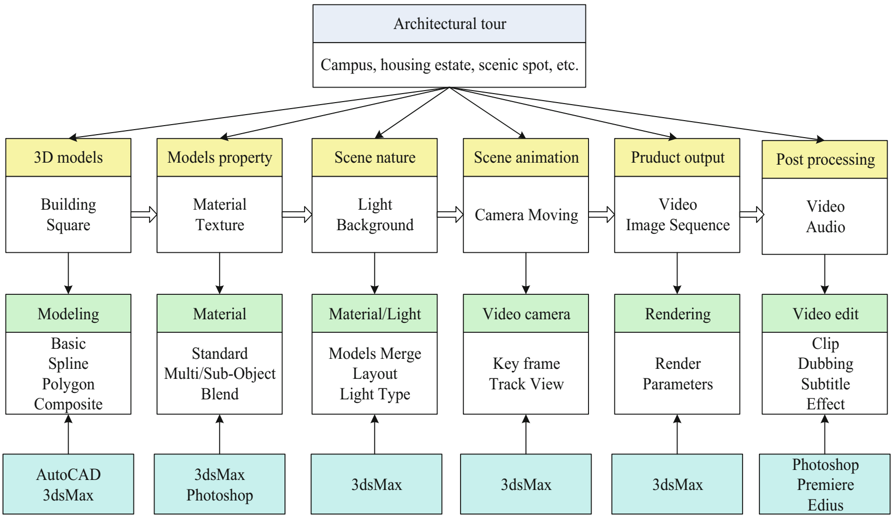

Fig. 3. Mind map of the course

In a group, we defined four personas: team leader, consultant, executor, and spokesman, who have the duty of their own as Table 3. Because it is a free combination, one pupil maybe has more than one duty and one persona may also be played by varying students, except leader. The team leader will be chosen by themselves. He must be willing to contribute and take responsibility for the completion of the project.

After a team is built, the members may talk over the project of the architectural tour with the teacher. First of all, the architecture or site should be selected. In general, the sites are in the campus or near the campus because students can conveniently gather data.

Table 3. Duty Of Four Personas

Personas	Duty
Leader	The student is responsible for organizing and coordinating all kinds of activities within a team, including labor division, project planning, discussion, and communication. A group leader should have strong leadership ability, organization skills, and be good at communicating with other persons
Consultant	The student has innovative awareness. He can continuously spark new solutions to problems using his creative power
Executor	The student is better at operating computers than others, so the capacity to operate the computer and solve problems is very important
Spokesman	The student has the linguistic capacity and can clearly express and share the idea of his team during the class hours of discussion

The teacher assesses the workload of architectural animation and writes down students' choices if the teacher thinks it is appropriate. And then, the teacher tells students about the process of the architectural tour and the requirements of the finished product. If the team thinks it is hard to complete, teachers will encourage them and convince them of offering help at each stage. Generally, the task of the project assignment is finished in the first week.

Following Guidance the Teacher's role is crucial in the whole learning process. Throughout the process, the teacher is the guide and peer, who provides the students with all the necessary support, including timely feedback and problem clues [20]. and an important component of PBL is that teachers provide feedback at critical points in the project. In turn, these reflections and recalibration facilitate deep learning [5]. Hence, from the second week, the teacher and students will communicate and discussion around the chosen project. In class, each speaker will give a progress report. The report contains a summary of the previous phase of work, problems that emerged, and possible solutions. When problems arise, topics of conversation are coming. Instead of providing the answers directly, the teacher may guide other groups of students to participate in the discussion. In most cases, the problems can be figured out by themselves. Meanwhile, instead of fear or boredom, they will be curious, learning, and happy about the project [4].

In the process of communication and discussion, students can also evaluate team members based on individual and team performance, which is an effective way to motivate students to become more involved in team activities. Through mutual feedback, students can reflect on their previous project-based learning process [29]. Comparing with answers afforded by the teacher, students are far more willing to accept the solutions of their own. As far as they are concerned, cooperation and competition coexist. Students gradually learn to regard assessment as a chance for deeper understanding [29]. What's more, students need to make a good preparation for communication and discussion before classes, which further stretches study time in class and improve the learning effect. Hence, every student can obtain a lot. To solve the problems, it is natural to require new knowledge points and new skills. At this time, the teacher can advise the members of each group on how to do next naturally.

Works Evaluation PBL Often requires students to complete a realistic product at the end of the project, such as a presentation or report [5]. Similarly, each group is required to show the video of 3D animation with an oral presentation. Each spokesman in the group elaborates their work in the following aspects: design scheme, key technique, learning gains, and so on. Meanwhile, some teachers or senior students, as judges, are invited to appraise students' work following their performance. when it comes to their products, students are very excited and glad to share their happiness and experience. This is also another style of communication and discussion.

4 Teaching Assessment

Teaching evaluation is a necessary step in all teaching processes. On the one hand, it can evaluate students' learning effect; On the other hand, it also provides a way to improve the teaching, curriculum, and environment. [22]. Since 2011, the PBL method using architectural tours has been implemented for liberal arts students to learn 3D animation with 3ds MAX. When the project was assigned, most students thought the project is difficult for them. They are not extremely adapted to the pedagogy of this kind at the beginning of the semester. The teacher has to encourage and guide these students. Works of former students can arouse their interest. We also find that communication and discussion between groups and members can provoke students' ambition, especially in the situation where students find their produce was not better than others'. At this time, they always try their best to learn, to practice than before spontaneously.

4.1 Learning Effectiveness

Tutors used to carry on lecture teaching with some unrelated or scattered examples for learning 3DsMax before. At that time students had no clear ideas of scenes' design and hardly paid more attention to some details. Therefore, even if they grasped some commands, they could not complete a perfect product. Now students who have project experience can do better than former students. According to a questionnaire, Fig. 4 shows the students' experience. 97 percent of students suggest that the length unit must be unified when many students cooperate. Most students also think that sketch, script, names of models, and material are important. Meanwhile, the optimization of scenes and the importance of layers are mentioned by most students. However, the students without project experience can hardly notice the details in Fig. 4, which shows that students' learning is effective.

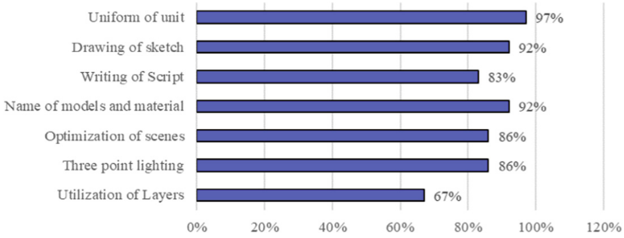

Fig. 4. Learning effectiveness

4.2 Students' Feedback

Regularly, students were required to evaluate each course in the teaching management system after the course is over. Some of the evaluating indicators are shown in Table 4. The statistical result of students' feedback is presented in Fig. 5, which indicated that students had positive comments on the method of PBL.

Table 4. Evaluating Indicators

ID	Name of indicators
1	Enable to improve teaching method
2	Enable to offer reasonable teaching design
3	Enable to inspire students to think
4	Enable to make students understand teaching content
5	Enable to increase students' ability to analyze and solve problems
6	Enable to raise students' interest and the ability to study independently
7	Enable to strengthen students' innovation consciousness and innovation ability

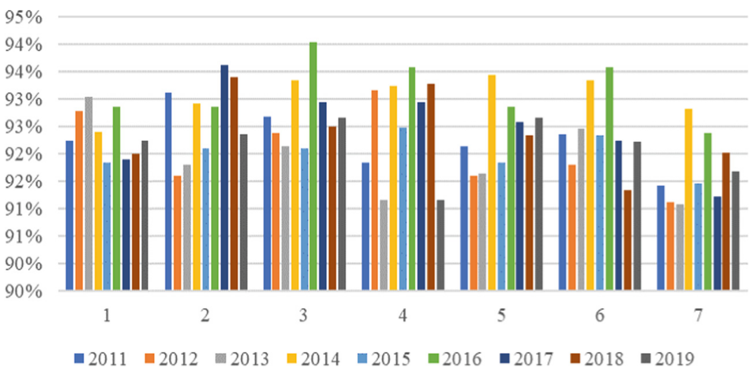

Fig. 5. Students' feedback

Figure 5 Shows the students' feedback on satisfaction. The satisfaction of each indicator is higher than 91.07%. The average satisfaction on these indicators is also up to 92.36%, 92.64%, 92.75%, 92.53%, 92.34%, 92.40%, 91.68%, separately. Most of the students have higher learning interests. They also displayed great initiative in their curriculum and projects. They no longer look at the curriculum or project as a difficult task. Moreover, they considered PBL as a good way to learn, which can strengthen their innovation consciousness and innovation ability, and other abilities, including analyzing and solving problems.

Figure 5 Also illustrates the usefulness of having project-based learning to learn 3D animation design. Real-world and familiar projects can help them learn the knowledge and skills of 3D animation step by step, and other high-level abilities, such teamwork, innovation, etc. In a word, project-based learning can motivate students to learn more new technologies and students will not be lost in the overall learning progress. But in traditional classroom teaching, even if the students pay more attention to the teacher's content, that will often happen.

5 Discussion and Conclusion

In the paper, a project-based approach with an architectural tour is proposed for the 3D animation design and liberal art students. According to our teaching experience, the PBL method enables students to actively participate in teaching activities, and acquire knowledge, skills, and a good learning experience. In the process of PBL, the design of the driving problem is very important, which is the core of project development. During the learning process of 3D animation design, the teacher condenses the project theme using an architectural tour. Therefore, related discipline core concepts will be permeated into a series of important and meaningful questions and students can be motivated to participate and stay focused on the target. When students of liberal arts design architectural tours, it is always accompanied by students' in-depth exploration of problems and flexible application of relevant subject knowledge. Many problems around the project, including how to build 3D models, how to set photorealistic material, how to light scenes naturally, etc. lead to students' in-depth learning of subject content, cultivate varied skills including critical thinking, teamwork, time management, problem-solving, responsibility, etc.

Students should have a say in the project, which can give students a sense of ownership and make them care more about the project and work harder. It is not true project-based learning if the teacher has designed each step in advance before the project begins, and the students only need to perform accordingly. Students should participate in the design and implementation of projects to a greater extent. They should have the right to express their opinions, from the design of the driving questions at the beginning of the project, to the project management process and role allocation, to seek more resources and external support, to the direction of the problem exploration and the final form of the work.

A high level of PBL can only be achieved if we regularly collect evidence about student learning and reflect it on teaching. In the whole process, students encounter many problems. They need to find out the causes of the problems and explain how to solve these problems. Through formative assessment, students can create and modify their works according to the feedback and suggestions from teachers' peers and communities. Such evidence-based practice also puts forward higher requirements on teachers' guidance ability. Teachers need to subtly provide feedback as students try to express their understanding and use procedural assessments to improve teaching. According to the practice of PBL using the architectural tour to learn 3D animation, we find that this method is effective, even if the students are from the majors of liberal arts.

Certainly, there are some important factors of PBL that instructors should pay more attention to. Firstly, in our project, the number of pupils per group is limited to three to five. When team members work together, they put less effort into achieving their goals than when they work alone [29]. If larger teams had been used in the procedure of PBL, the social loafing phenomenon is even more serious. Therefore, how to reduce social loafing and improve teamwork is an important research topic in PBL teaching or collaborative learning. Secondly, PBL takes too much time [9]. A few students with the optional public course even lose their patience and give up. These beginners dislike the PBL teaching method, working in groups, and relying on the performance of others. In contrast, they prefer traditional teaching methods. Therefore, these students need more attention from the teacher.

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Exploration of C++ Teaching Reform Method Oriented by Ability Output

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Abstract. Aiming at the main problems existing in traditional C+ + curriculum teaching, relying on the background of the "new engineering" era, a "five in one" C++ teaching innovation mode is proposed. The "five in one" means: a national quality resource sharing course, a system combining competition and teaching, a C++ intelligent examination system, an ideological and political classroom, a laboratory combining competition and teaching. The "five-in-one" teaching model highlights the "student-centered" teaching concept. According to the teaching objectives of each class, it is cleverly integrated into the curriculum ideological and political content with "problem solving" and "live-code" as the main teaching line. Information-based teaching is used as a way to promote the integration of students' theory and practice with ACM/ICPC, organically integrate process assessment and summative assessment, and implement diversified assessment forms. The results of more than ten years of practical teaching show that the "five-in-one" teaching innovation mode effectively cultivates students' computational thinking, and significantly improves students' programming ability and innovation ability. In the previous ACM/ICPC, our students have repeatedly achieved good results. At present, the "five-in-one" teaching innovation mode has been effectively promoted and applied in the three campuses of our university, which has a certain leading and exemplary role in cultivating the strong professional programming skills, computational thinking, the family and country feelings, the global vision and the all-round development of the top-notch innovative talents in the computer field.

Keywords: ACM/ICPC · five in one · teaching innovation · C++

1 Introduction

1.1 Overview of ACM/ICPC and C++ Course

The Association for Computing Machinery / International Collegiate Programming Contest (ACM/ICPC) is the most influential international computer competition for college students from all over the world. It is a stage for college students majoring in computer science to show their talents, a direct embodiment of the achievements of computer education in famous universities, and the best platform for information companies to communicate with the world's top computer talents [1]. The ACM/ICPC is a completely

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closed competition, which can conduct a real-time comprehensive inspection of students' abilities, and its results are more authentic. Therefore, it has become a hot spot pursued by domestic colleges and universities. It is an important activity for cultivating outstanding talents in an all-round way, and it has an important value orientation for the cultivation of computer professionals. Since the ACM/ICPC has set a set of the reasonable competition ranking and challenge rules, it provides a complete practice mode for learning and using programming languages and algorithms, so that students can be proud of being proficient in programming and form a positive and self-directed learning atmosphere. At present, some colleges and universities have applied the ACM model to the teaching process of the basic software courses such as "Data Structure" and "Algorithm Design and Analysis" and achieved the remarkable results [2, 3].

"Advanced Language Programming (C+ +)" is a basic computer course offered by most domestic colleges and universities for undergraduates. It is not only strong in theory, but also in practice. The quality of the experimental teaching effect directly affects the overall teaching quality and effect. Aiming at the common problems in the traditional C++ teaching mode, the author proposed a C ++ teaching reform mode based on ACM/ICPC by applying the ACM mode to the C+ + teaching method reform in our school. This model cultivates students' interest in participating in ACM/ICPC, greatly improves students' initiative and enthusiasm for learning, strengthens the cultivation of teamwork spirit and innovation ability. The proposed mode improves teaching quality and teaching level, and is highly praised by students, which has a certain demonstration effect on the teaching reform of C ++ courses in our school. Now this reform has been fully launched among the freshmen of computer science of our university [4–6].

1.2 Key Issues to Be Solved in Course and Teaching Reform

There are three key issues that need to be addressed in the teaching reform process as follows.

(1) Theoretical teaching: Firstly, the course ideology and politics have not been organically integrated into the whole process of course teaching, with few ideological and political cases and cannot be naturally integrated into the course teaching contents. Secondly, students are not very interested in purely theoretical C ++ teaching. Thirdly, the course contents and the learning resources are lagging behind, lack of modernity and advancement. Finally, the classroom teaching methods are outdated. The teachers ignored the program demonstration and the running links. The teaching method does not highlight the dominant position of students, resulting in the low student participation and difficulty in the teacher-student interaction.

(2) Practical teaching: The C++ teaching method focuses on theoretical teaching and ignores practical teaching. There is a big difference in programming ability between students. In a small number of experimental courses, there is a lack of the advanced, innovative and exploratory experiments. The practice content is solidified in a single form. There is no test data for programming questions or the test data is not considered comprehensively. The training links of students' practical innovation ability and the spirit of craftsmen of a great country are missing, which cannot meet the training requirements of the new engineering talents. It is difficult for the students to solve the practical problems from the perspective of the computer, that is, students' computational thinking cannot be effectively cultivated.

(3) Course assessment: The assessment method of C++ tends to focus on the results and ignore the process. The assessment method cannot stimulate and promote the students' learning in the whole process. It focuses on the summative assessment and ignores the process assessment. Therefore, the current assessment method is not reasonable enough.

2 Research Work and Purpose

2.1 Innovative Contents

Aiming at the main problems existing in the teaching of traditional C+ + courses, relying on the background of the "new engineering" era, a "five-in-one" C ++ teaching innovation mode is proposed. The "five in one" means: a national quality resource sharing course, a system combining competition and teaching, a C++ intelligent examination system, an ideological and political classroom, a laboratory combining competition and teaching. The "five-in-one" is interconnected, coordinated, promoted and complemented to form an organic whole.

This teaching innovation mode highlights the "student-centered" teaching concept, and ingeniously integrates the ideological and political contents of the course according to the teaching objectives of each class. Taking the "problem-solving" and the "live code" as the main line of teaching, using information-based teaching as a means, using the ACM/ICPC competition to promote the integration of students' science and practice, organically combining the process assessment and the summative assessment, this course implements a variety of assessment forms.

Firstly, deeply dig the ideological and political education resources contained in the C++ course contents, and integrate the course ideology and politics into the whole process of teaching. In the specific process of the curriculum ideological and political construction, innovative thinking is needed. New thinking is used to generate new ideas. The new ideas are used to seek the new development. The new development is used to promote the new methods. The new methods are used to solve the new problems. The innovative development of the curriculum ideology and politics is thus realized. Mining the ideological and political resources according to the C++ course contents, such as: when teaching the selection statements, we can tell the student that the Ariane 5 launch vehicle failed for the first time due to the bug so that students can realize the importance of writing a safe and high-quality code, and realize that programming must have a rigorous logical thinking. When teaching the repetition statements, by taking the virus of a panda burning incenses or the latest ransomware virus as an example to guide students to think about the world outlook, the life outlook, values and other issues. The ideological and political construction of the curriculum helps to cultivate outstanding talents with the family and country feelings, the international vision and the responsibility.

Secondly, by taking the "problem-solving" and the "live code" as the main teaching line, and combining the theory with practice, we establish teaching the themes and the live code cases. The "Problem-solving" means that the main knowledge points of the

C ++ course are introduced in the “problem-introducing”. Let students know the reasons for the introduction and application scenarios, and then condense the knowledge of each chapter into 4 ACM-style questions with a certain degree of challenge. Taking the "programming language for solving practical problems" as the main line, we will carry out teaching in accordance with aptitude and layered innovative teaching, so as to improve students’ interest in learning, the programming ability and the innovation ability. The "Live code" means that the main knowledge points of the C++ course are demonstrated through one or more complete runnable C++ programs, rather than just explaining the syntax or the code fragments, which can improve students’ interest in learning and focus. This course cultivates students’ computational thinking and innovation ability by describing the programming ideas of C ++, and lays a solid foundation for subsequent courses such as "Data Structure" and "Algorithm Design and Analysis". The traditional teaching method only shows PPT in the classroom. Although the PPT also includes the theoretical knowledge points and the program codes, the students are not very interested in the PPT and the learning effect is not ideal. Through the live code and the heuristic teaching methods, students can visually feel and observe the dynamic changes of the relevant memory after each statement is executed, so as to not only know the function of each program, but also know why. Therefore, this teaching method can greatly improve students’ attention, which can greatly stimulate students’ enthusiasm for learning. Heuristically demonstrate the course contents according to the theme, make the code live on the screen, deepen the understanding of knowledge points, and gradually cultivate students’ interest in learning.

Thirdly, the ACM/ICPC promotes the integration of the students’ theory and practice, and cultivates the students’ practical ability, the innovation ability and the teamwork spirit. The ACM/ICPC is a completely closed competition, which can conduct a real-time comprehensive inspection of students’ abilities, and its results are more authentic. Therefore, it has become a hot spot pursued by domestic colleges and universities. Many topics do not have the ready-made algorithms and require the innovative spirit. Because the ACM/ICPC involves a wide range of knowledge, for the freshmen, computer-related knowledge is almost blank. How to gradually cultivate the programming interest without fear of difficulty is a key problem to be solved in this course reform. In the process of C++ reform based on the ACM/ICPC, the general principle of the course questions is: according to the format of the ACM/ICPC questions, the important knowledge points of each chapter are integrated into 4 questions (according to the difficulty factor, divided into A, B, C, and D, in order to teach students in accordance with their aptitude and deal with the problem of stratified teaching).

At present, although our school has applied the ACM model to the reform of the C++ teaching method and achieved obvious teaching effects, the final exam of this course is still a traditional exam with paper. One of the biggest drawbacks of this exam is that teachers can not make a fair, impartial and effective judgment on the only subjective question (usually 2 programming questions, whose score accounts for about 20–30% of the total score of the test paper). If the problems in the test paper does not pass the compilation, it is difficult to judge whether the code is 100% correct from the lengthy code written by the students. In addition, the scoring of programming questions varies from person to person, and it is difficult to grasp the scoring standard. Therefore, the test results of this course are inherently lack of fairness and impartiality. Although some paperless examination systems for programming languages have appeared [7], these systems can only automatically score three types of objective questions, such as judgment questions, fill-in-the-blank questions, and multiple-choice questions. Therefore, in order to make the C++ examination more scientific and objective, aiming at the defects of the general paperless network examination system, based on the ACM/ICPC platform, the author proposed a new C++ paperless examination system and successfully solved the defects of the general paperless network examination system, and realized the fair, impartial and automatic scoring of the C++ paperless examination. In addition, in order to prevent students from intentionally avoiding the knowledge points to be assessed, the author improved the traditional OJ system, developed a new keyword-oriented combination system of competition and teaching, and obtained a software copyright.

2.2 Innovation Processes

The innovation process of this course is divided into four parts as follows.

(1) Innovation in the teaching concept: Aiming at cultivating the top-notch innovative talents in the computer field with the strong professional programming ability, the computational thinking, the family and national feelings, the global vision, and the all-round development, this course strives to highlight the "student-centered" teaching concept.

(2) Innovation in the teaching mode: To promote teaching through competition, a "five-in-one" teaching innovation mode is put forward to cultivate the students' practical ability, the computational thinking ability and the innovation ability. "Computational thinking" is an important means for human beings to solve problems in the future society. It involves using the basic concepts of computer science to solve problems, design systems and understand human behavior, rather than making people operate mechanically like computers. The construction of new engineering majors and the educational reform put forward the cultivation of students' scientific thinking ability.

Taking the "problem-solving" and the "live code" as the main teaching line, according to the characteristics of the C++ course form and content, the rational use of online teaching platform and the modern educational information technology can highlight the characteristics of C++ course and effectively cultivate students' computational thinking ability. According to the teaching feedback, through teaching students in accordance with their aptitude, the exploratory experiments that are more in line with students' cognition and learning laws are designed in layers, so as to effectively improve students' practical ability and innovation ability.

According to different knowledge points and teaching objectives in each class, actively carry out the inquiry (the exploratory knowledge points), the seminar (the algorithmic knowledge points), the game (the game projects), the heuristic (the expandable knowledge points), the case-based (actually occurring cases), the project-driven (the practical projects), the problem-oriented (the control structures, the functions and the class-related knowledge points) and other teaching activities to achieve the teacher-student interaction, the student-student interaction, and increase the student engagement.

(3) Innovation in the teaching contents: Taking the golden class standard as the curriculum construction requirements, insisting on taking the morality and cultivating people as the central link, the ideological and political work throughout the whole process of the education and teaching, realizing the whole process of the educating people and all-round education, and continuing to guide students to have a firm belief in the core values of the socialism. The scientific and cutting-edge teaching contents are continuously built. The C++ standard is updated almost every 3 years. The teaching contents of each academic year are updated according to the actual situation and keeps pace with the times, such as: adjustment of teaching cases, redesign of teaching situations, an introduction to recent updates to the C++ standard, etc.

(4) Innovation in the assessment methods: Organically combine the procedural assessment with the summative assessment, implement diversified the assessment forms, and cultivate the students' hands-on ability, the computational thinking ability and the innovation ability. In the teaching process of this course, emphasis is placed on the assessment of the students' practical ability. The grades are divided into three parts, namely: the daily homeworks and the classroom performance, the OJ experiments, and the final exam. The proportions are: 10%, 30%, and 60%, respectively.

2.3 Online Judging System

The ACM online judging system (referred to as the OJ system) is an online real-time submission system that integrates the programming competition, the competition training, the course experiment, and the daily practice. The system can provide a large number of competition questions for students to practice or compete. Students submit the program code to solve the relevant competition questions online. The system can automatically compile the program code, generate an executable file, and test the program according to the stored test cases.

In terms of teaching reform, the author mainly reformed the two courses "Advanced Language Programming (C++)" and "Algorithm Design and Analysis" in combination with the ACM competition. A competition-teaching integration system (http://222.201.146.218) is used for teaching and doing experiments. The system is currently running stably. As a platform for students to get started with "Advanced Language Programming (C++)", the competition-teaching system plays an important role in subsequent courses such as "Data Structure" and "Algorithm Design and Analysis". The practical teaching of the competition teaching system can be carried out directly through the network, and it is not limited by time and space.

Different from the usual way of submitting the assignments, the students not only have to write the programs without compilation and logic errors, but also must comply with the input and output formats of the ACM/ICPC to be correctly accepted by the system. The general principle of the author's questions in the combination of competition and teaching is: according to the format of the ACM/ICPC questions, the important knowledge points of each chapter are integrated into 3 to 4 questions. Moreover, in the process of the C++ reform based on the ACM/ICPC, the characteristics of the author's questions are as follows:

(1) Most of the ACM/ICPC test questions are adapted from the exercises of the C++ textbook.

(2) The knowledge points of each chapter are organically integrated into the prepared ACM/ICPC test questions. Students not only master the knowledge points of each chapter, but also understand the format and the style of the ACM/ICPC questions, thus killing two birds with one stone.

As far as the examination system is concerned, the C+ + objective questions, namely: judgment questions, multiple-choice questions, and fill-in-the-blank questions, are relatively simple to implement and can be accurately scored. However, C++ subjective questions, namely: programming questions, as an important question for assessing students' programming ability, are compulsory questions in various programming languages, and are subjective questions. If the possibility of plagiarism is excluded, the programs written by students are almost different, so this type of question has always been marked by the teacher himself, which is the main reason why many C++ paperless examination systems cannot be completely automatically scored. Taking the OJ system as the basic platform, our exam system will be keyword-oriented to write programming questions.

In view of the fact that the traditional OJ system cannot judge whether the source code of students really meets the knowledge points to be assessed by teachers, by setting the keywords that must appear in the source code and the keywords that are forbidden to appear, the author proposed a method based on keywords [5]. The keyword-oriented ACM/ICPC competition-teaching combined system will be able to effectively and automatically detect whether the students have submitted questions according to the teacher's requirements, thus effectively preventing students from attempting to avoid the knowledge points to be assessed, and greatly reducing the workload of the teachers.

The international description of an ACM/ICPC question includes the following 5 parts, and any part is indispensable:

The first part: "Description" mainly describes the task to be solved.

The second part: "Input" mainly describes the data to be input.

The third part: "Output" mainly describes the data to be output.

The fourth part: "Sample Input" gives the sample input when the program is running.

The fifth part: "Sample Output" gives the sample output when the program is running.

It is precisely because the international ACM/ICPC test questions only focus on the input, the output and the algorithm itself, and do not take into account the characteristics of C + + teaching, so compiling the questions in the above way leaves a lot of space for students to avoid the assessment knowledge points. In view of this, in addition to the above 5 required parts, the author has added 2 other optional parts, namely:

The sixth part: "Keyword(s) that Must be Used", which specifies the keywords that must appear in the program.

The seventh part: "Keyword(s) that Mustn't be Used", which specifies the prohibited keywords in the program.

If the sixth and seventh sections do not fill in anything, then after editing the question, "Keyword(s) that Must be Used" and "Keyword(s) that Mustn't be Used" will not be displayed on the web page for the following reasons.

First: Because these two items are set to be empty when the teacher edits, there is no need to display them.

Second: In line with the international ACM/ICPC question-setting style. That is to say, the style of the questions in this system not only inherits the style of the international

ACM/ICPC and the competition, but also expands the style of the questions, and has the style of the questions combined with the C++ teaching.

Without loss of generality, suppose there is a programming problem whose function is to display the input string on the screen. Next, we will explain the principle of the question preparation in the new keyword-oriented competition-teaching combination system.

The function to be realized in this question is to input a string from the keyboard and display the content of the input string from the screen. According to this, we need to fill in the 5 required items of the system “Description”, “Input”, “Output”, “Sample Input” and “Sample Output”, etc. For the two items “KeyWord(s) that Must be Used” and "KeyWord(s) that Mustn’t be Used", according to the specific knowledge points to be assessed in this question, we can stipulate that the keyword that must be used is cin, and the forbidden keyword is scanf. With this restriction, students will have to use C++ language for programming, but at this time students can still choose to use the object-oriented method or the procedure-oriented method. Therefore, if we add another class to the keywords that must appear, then the student will have to use the object-oriented programming method to write the program. The input values for the 7 parts of Problem 2015 on the platform are given below.

Part 1: “Description” input “Input a string, and output a string.“.

Part 2: “Input” Enter “a string”.

Part 3: "Output" Enter "a sring”.

Part 4: “Sample Input” Enter “cin”.

Part 5: “Sample Output” Enter “scanf”.

Part 6: “Keyword(s) that Must be Used” Enter “Hello world!”.

Part 7: “KeyWord(s) that Mustn’t be Used” Enter “Hello world!”.

Based on this design, no matter how the student’s code changes, the program must be compiled through the competition-teaching system, and the system’s test data is used to verify the correctness of the program, thereby greatly improving the fairness of the question judgment and ensuring the fairness of the test. It reduces the workload of teachers to review program questions, thus arousing students’ interest in learning and promoting students to improve their hands-on programming ability.

Therefore, the paperless examination system based on the ACM/ICPC can adapt the subjective questions into the objective questions, which is conducive to the realization of complete fairness, impartiality and automatic scoring of the entire examination system.

2.4 Implementation Methods

This course is organized and implemented by a combination of classroom teaching, computer experiments, extracurricular homework, and online teaching. According to the nature of the C++ course and the requirements of the course objectives, the process, the form, the content and the informatization means of the course assessment are taken as the starting point, the whole process of students’ learning is concerned, and the procedural assessment and the final assessment are organically combined. A variety of assessments are selected, such as the written test, the computer test, the classroom discussion, the game design, the debate, and the program design competition for the freshmen. Comprehensively evaluate and test students' knowledge mastery, understanding, and application ability from multiple perspectives. By combining with the frontiers of disciplines closely related to the C++ practical problems or engineering the practice problems, the non-standardized answer questions are added to reflect the openness, flexibility and exploratory nature of the assessment content. Students' knowledge application ability, problem-solving ability and innovation ability are examined.

In terms of C++ classroom teaching reform, combined with the ideological and political elements of the course, teaching methods such as the "live code", the "group discussion method", the "heuristic method " and the "game style" are mainly adopted.

(1) Pre-class stage: Through Rain Classroom (a teaching plugin), the rich teaching resources and the pre-class test questions can be easily inserted into the slides, and pushed to the students' WeChat anytime and anywhere to facilitate the courseware preview and the pre-class test.

(2) Mid-class stage: Implement the quick in-class tests and carry out the innovative teacher-student interaction. One-click to send the exercises integrated into PPT, which can be renewed within a limited time, lecture at any time, and test at any time. Bullet screens, submissions, classroom red envelopes, random roll call, large class teaching can also allow everyone to speak, and activate the classroom atmosphere.

(3) After-school stage: According to the teaching contents, push the complete homework questions, subjective and objective questions, voting questions, attachment answering, photo uploading, and voice response, which can meet the different homework needs. After each chapter is finished, 4 programming questions will be arranged on the competition-teaching platform to consolidate the students' programming foundation and cultivate the students' ability to draw the inferences from one instance and draw the parallels by analogy.

(4) Teacher reflection stage: Driven by the panoramic data provided by Rain Classroom, analyze the teaching data of the whole cycle, before class - during class - after class, the data of each step can be seen, providing effective teaching reflection data for the next round of teaching.

In terms of the course assessment reform, the transition from C++ paper-based examinations to a paperless examination system will be promoted. The online examination system will fully support various question types of the offline examinations, such as: true and false questions, multiple-choice questions, multiple-choice questions, writing result questions after reading a program, fill-in-the-blank questions, programming questions, etc. In terms of the application of the teaching information technology means, we will use the competitive teaching system, QQ answering group, and the rain classroom plug-in to innovate and lead the classroom revolution: promote blended teaching, formative evaluation, and multi-channel interaction.

3 Effectiveness of Teaching Innovation

In the first semester of the 2010–2011 school year, the author conducted the first pilot work on the combination of "Advanced Language Programming (C+ +)" teaching and ACM competition in Class 5 majoring in the Information Security, and achieved the certain results. From the second semester of the 2010–2011 school year, the teaching of the combination of "Advanced Language Programming (C++)" and ACM competitive teaching has been officially implemented [4–6]. In the first semester of the 2011–2012 school year, the first pilot work was carried out in the Class 1 and Class 2 majoring in the Computer Science and Technology, which combined the teaching of "Algorithm Design and Analysis" with the ACM competition. The pilot was very successful. From the second semester of the 2011–2012 school year, the teaching of the combination of "Algorithm Design and Analysis" and ACM competitive teaching has been officially implemented [3]. The early teaching practice of this course shows that the combination of competition and teaching has greatly cultivated students' interest in participating in the ACM/ICPC, improved the students' initiative and enthusiasm for learning, and strengthened the cultivation of teamwork spirit and the innovation ability, which has been widely welcomed by students.

At present, all the teachers of the C++ course in our university are using this system of competition and teaching, and it has been promoted and applied in the three campuses of our university. In recent years, with the enhancement of students' hands-on programming and innovation ability, our ACM training teams have repeatedly achieved good results in the ACM/ICPC, the ACM-CCPC and the ACM-GDCPC competitions over the years [8–13], such as: in the 43rd ACM/ICPC competition, they achieved 2 golds, 7 silvers and 2 bronzes, and in the 44th ACM/ICPC competition, they achieved 3 golds, 6 silvers and 4 bronzes. In addition, during the 2020 season, a total of 9 teams were sent to participate in 6 Asian regional competitions of the International College Students Programming Competition. In the competition of the competition station, they achieved 3 golds, 4 silvers and 2 bronzes, respectively. The 7 teams participated in 4 sub-stations and 1 national final of the China University Student Programming Contest, and won 2 golds, 2 silvers and 3 bronzes [14]. In the competition, the "Stars Shining" team won the 9th place in the Yinchuan Division where more than 500 teams and nearly 200 colleges and universities participated. The team ranked 14th and our school ranked 12th. The team "CSP-Junior" ranked 5th in the Macau Division. In addition, the members of the training team of our college also participated in the "Yuanguang Cup" Guangdong-Macao Computer Programming Contest and the Greater Bay Area Youth Informatics Programming Contest this year, and won the championship of these two provincial competitions.

In the past five years, the total number of student medals in our school has reached more than 60, of which the number of gold, silver and bronze awards in the ACM/ICPC is 6, 14 and 11, respectively, and in the ACM/CCPC is 2, 5, and 4, respectively. The number of first prize/gold prize, second prize/silver prize, third prize/bronze prize in ACM/GDCPC is 7, 7, and 7, respectively. The above achievements fully demonstrate that the students trained by our school have the solid and strong professional competitiveness, and are a direct reflection of the achievements of our school's implementation of the combination of the competitive teaching and teaching reform over the years. In addition, the student evaluation score of the courses taught by the author has always been at the forefront of the college, with a recent score of 4.981 out of 5.

Therefore, from the actual teaching effect and the results of the ACM competition, the "five-in-one" innovative teaching mode has greatly improved the students' learning initiative, the enthusiasm and the practical ability, and cultivated the students' interest and the innovative ability to participate in the ACM/ICPC, which has significantly improved the teaching quality and teaching level of this course. The innovative teaching mode has been praised and generally welcomed by students, and achieved remarkable teaching results.

4 Innovation and Sharing Results

The ACM/ICPC is the most influential international computer competition for college students from all over the world. It is a stage for college students majoring in computer science to show their talents. It is a direct reflection of the achievements of the computer education in famous universities. It is the best platform for information companies to communicate with the world's top computer talents. The following is a summary of the sharing of teaching innovation achievements in this course:

(1) Innovation in theoretical teaching: In response to the problem that the pure theoretical teaching methods are boring and cannot stimulate the students' interest in learning, through the student-centered, the ACM competitions to promote the integration of theory and practice, with the "problem-solving" and the "live code" methods as the main line of teaching, using information-based teaching as a means, the author in this paper put forward a "five-in-one" teaching innovation mode. The "five in one" means: a national quality resource sharing course, a system combining competition and teaching, a C++ intelligent examination system, an ideological and political classroom, a laboratory combining competition and teaching. The "five-in-one" is interconnected, coordinated, promoted and complemented to form an organic whole.

(2) Innovation in practical teaching: In response to the large difference in programming ability among students, the experimental questions and the exploratory questions are set up in layers and effectively cultivate the students' practical ability and the innovation ability. A large number of outstanding talents have been delivered to the ACM training team. In addition, the traditional OJ system was improved, a keyword-oriented competition-teaching combined system was designed, and a software copyright was approved.

(3) Innovation in course assessment: Aiming at the shortcomings of the C++ paper-based examinations and the traditional course assessment methods, a C++ multi-question intelligent online examination system was designed, and a software copyright was approved. The system solves the problem of unfairness in the programming questions in the traditional paper-based exams. In addition, in the form of the assessment, a multi-process and multi-angle course assessment method is proposed by organically combining the procedural assessment and the summative assessment.

(4) Innovation in talent training: In terms of guiding undergraduate scientific research papers, the author has guided a number of undergraduates to publish more than 20 scientific research papers of algorithm type, including the top domestic journal such as "Journal of Software" and the top international journal such as "IEEE Transactions" on Image Processing" [15], which fully reflects that undergraduates also have the strong programming ability and the innovation ability.

In a word, the "five-in-one" teaching innovation mode has been effectively promoted and applied in the three campuses of our university, which has a certain leading and exemplary role in cultivating the strong professional programming skills, the computational thinking, the family and country feelings, the global vision and the all-round development of the top-notch innovative talents in the computer field.

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An Effective Approach for Teaching Runtime Environments in a Compiler Construction Course

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Abstract. Compiler construction course is one of the important professional courses for computer science and technology majors. The study of compiler construction is a practical exercise in software engineering. The teaching of compiling techniques can be effectively enhanced by compiling practical examples in compiler constructing courses. In this paper, an effective approach for teaching runtime environments in a compiler construction course is presented. First, concepts such as activation records, control link, access link, and pointer to the current activation are introduced to the students. Then, we show the implementation techniques of activation records and data access method the target computer by using debug tool for C++ development environment on C language programs. The approach proposed in this paper is applied in the compiler construction course, which deepens students' understanding of programming language, and cultivates students' abstract thinking, logical derivation and generalization ability. This approach method also helps to improve their programming skills.

Keywords: Compiler · Runtime Environments · Exploratory · Active Learning

1 Introduction

A compiler can convert a language program (called a source language program) into another language (called a target program), and the latter is logically equivalent to the former. The source language is a high-level language such as FORTRAN, C/C++, or Java, while the target language is a low-level language such as assembly language or machine language [1]. Please note that the first paragraph of a section or subsection is not indented. The first paragraphs that follows a table, figure, equation etc. does not have an indent, either.

Compiler construction course is one of the important professional courses of computer science and technology. The main goal is to study the basic principles and basic implementation methods of programming language compilation construction, and its research object is the compiler of programming language an important part of computer core course. The study of compiler construction is a practical exercise in software engineering. Many theories, concepts, principles and software development techniques

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support the process of compiler construction [2]. It can effectively strengthen the teaching of compilation skills by compiling practical examples in compiler constructing courses. Debug tool for C++ development environment can help students understand the concept of supporting the compilation process.

The compiler construction course at our school is taught in the third year of a computer science and techniques undergraduate program. Students in compiler construction course are required to have learned assembly language, computer organization and structure, C/C++, data structure and operating system. Through the study of compiler construction course, students can master the theory and method of compiler design and implementation. The subjects included in the course of study are lexical analysis, syntax analysis, syntax-directed translation, intermediate code generation, runtime environments, code optimization, and object code generation. After learning the compiler construction course, students must be able to develop compilers for programming languages. Tools such as lex and yacc can be used to develop compilers [3]. However, lex and yacc are used for lexical analysis and syntax analysis, not for runtime environments [4].

There are many abstract concepts in compiler construction course, which are difficult for students to understand [5]. In order to teach students better and better, educators implement the student-centered learning approach [6]. The student-centered learning approach is characterized by a problem-oriented method. When students engage in problem-solving activities, they will learn better [7]. Students can get very good learning effect through analysis, discussion and debate in the course [8].

Students need an environment conducive to learning and understanding basic principles [9]. With the rapid development of computer techniques, new methods and appropriate software tools and environment can help teachers teach more successfully [10]. Acquiring knowledge through environmental experiments helps to learn and understand basic principles in an efficient, direct and lasting way [11]. Otherwise, students quickly lose interest and their learning motivation decreases [12].

This paper focuses on the approach for teaching runtime environments in a compiler construction course. The runtime environment organizes and manages the information required by the object code runtime, including variables, registers, temporary variables, parameter transfer, process return address, process link, and so on. After learning the concept of runtime environment, students still can't understand how activation records are organized and how data is accessed on the target computer because all textbooks of compiler construction do not describe the implementation techniques of activation records on the target computer.

In this paper, the authors' experience with using debug tool for C++ development environment for teaching runtime environments is described in a compiler construction course. First, concepts such as activation records, control link, access link, and pointer to the current activation are introduced to the students. Then, we show the implementation techniques of activation records and data access method the target computer by using debug tool for C++ development environment on C language programs.

The rest of the paper is structured as follows. Section 2 presents an effective approach for teaching runtime environments in a compiler construction course. Section 3 compares the approach presented in this paper with traditional teaching approach and analyzes the evaluation of the approach presented in this paper. Section 4 gives the conclusion for this paper.

2 Runtime Environments

During the execution of the program, the data in the program is accessed through the corresponding storage unit. In a program language, the storage units used in a program are represented by identifiers. The memory addresses corresponding to them are allocated by the compiler when compiling or the target program generated by it runs. Therefore, storage organization and management is a complex and very important problem for compilers.

The runtime environment is responsible for the storage space allocation of data objects in the source program and how to access data objects when the object code runs.

In order to manage the information required by the process in one execution, a continuous storage block is used. We call such a continuous storage block activation record. When a procedure is called, a new activity of a procedure is generated, and the relevant information of the activity is represented by an activity record, which is pushed onto the stack.

```
#include<stdio.h>
#include<stdlib.h>
void f(int x, int y)
{
     int a[10];
     int z;
     int i;
     for(i=0; i<10; i++)
       a[i]=i;
     z=x+y;
     printf("%d\n",z);
}
int main()
{
   int a, b;
   a=10;
   b=20;
   f(a, b);
   return 0;
}
```

Fig. 1. An example of C program.

After students learn about the concept of activation records, control link, access link, and pointer to the current activation record, we give a C program as following Fig. 1. The concept of runtime environment is best understood by giving the function call activation record structures. The activation record for a call to f is shown in Fig. 2. In C/C++ language function arguments must be pushed on the stack in reverse order (last to first). The pointer to the current activation record is usually called the frame pointer, or fp.

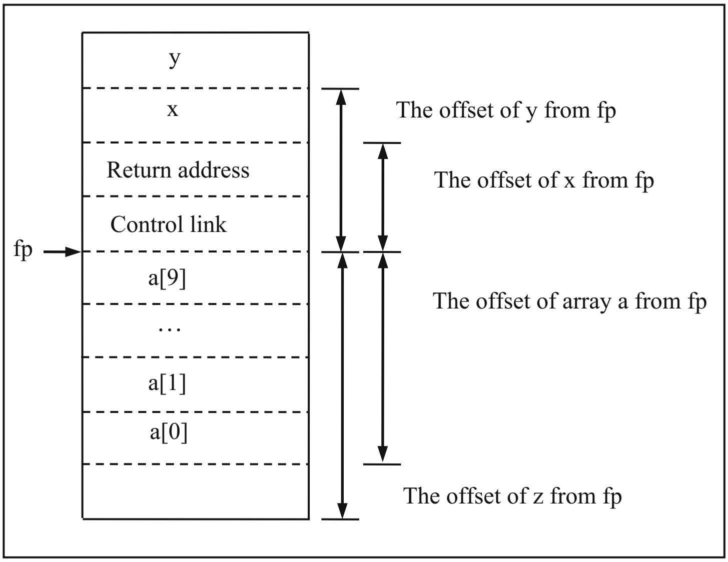

Fig. 2. The activation record for a call to f of Fig. 1.

Assuming four bytes for integers, four bytes for addresses, and eight bytes for double-precision floating point, we would have the following offset values, which are all computable at compile time:

Now an access of, say, a[i] would require the computation of the address

$$(-40 + 4 * i)(\text{fp})$$

Table 1 shows the offset of variables in activation record of function f in Fig. 2.

Table 1. The offset of variables in activation record of function f.

Name	Offset
y	+12
x	+8
a	−40
z	−44

After the above explanation, students can understand the concept of activation records and the methods of data access in functions. But students still can't understand how activation records are organized and how data is accessed on the target computer. Students strongly want to know the implementation techniques of activation records on the target computer.

We want students to generate assembly language code from function f on C language program in Fig. 1 by using debug tool for C++ development environment (Microsoft Visual C++ 6.0). The assembly language code is shown in Fig. 3.

Through Fig. 3, students can find that the control link of activation record is actually implemented by ebp register. The following instruction

push ebp

saves the caller's control link.

The pointer fp to the current activation record is actually ebp register. The following instruction

mov ebp esp

```
3:     void f(int x, int y)
4:     {
00401010   push        ebp
00401011   mov         ebp,esp
00401013   sub         esp,70h
00401016   push        ebx
00401017   push        esi
00401018   push        edi
00401019   lea         edi,[ebp-70h]
0040101C   mov         ecx,1Ch
00401021   mov         eax,0CCCCCCCCh
00401026   rep stos    dword ptr [edi]
5:         int a[10];
6:         int z;
7:         int i;
8:         for(i=0; i<10; i++)
00401028   mov         dword ptr [ebp-30h],0
0040102F   jmp         f+2Ah (0040103a)
00401031   mov         eax,dword ptr [ebp-30h]
00401034   add         eax,1
00401037   mov         dword ptr [ebp-30h],eax
0040103A   cmp         dword ptr [ebp-30h],0Ah
0040103E   jge         f+3Ch (0040104c)
9:             a[i]=i;
00401040   mov         ecx,dword ptr [ebp-30h]
00401043   mov         edx,dword ptr [ebp-30h]
00401046   mov         dword ptr [ebp+ecx*4-28h],edx
0040104A   jmp         f+21h (00401031)
10:        z=x+y;
0040104C   mov         eax,dword ptr [ebp+8]
0040104F   add         eax,dword ptr [ebp+0Ch]
00401052   mov         dword ptr [ebp-2Ch],eax
11:        printf("%d\n",z);
00401055   mov         ecx,dword ptr [ebp-2Ch]
00401058   push        ecx
00401059   push        offset string "%d\n" (0042201c)
0040105E   call        printf (004010a0)
00401063   add         esp,8
12:    }
```

Fig. 3. The assembly language code of function f in Fig. 1.

causes ebp register to point to the current activation record and data is accessed through ebp register. The location of the data in activation record (stack) is shown in Table 2. The offset of data in Table 2 is the same as in Table 1.

Table 2. The location in stack of variables in function f.

Name	Location in stack
y	[ebp+0ch]
x	[ebp+8]
a	[ebp−28h]
z	[ebp−2ch]

Through case teaching, teachers guide students to find and solve problems, students' interest in learning has increased. At the same time, it strengthens students' learning of assembly language.

Recursively calculating n! C program is shown as Fig. 4. We also students to generate assembly language code from C language program in Fig. 4 by using debug tool for C++ development environment. The assembly language code is shown in Fig. 5.

```
#include<stdio.h>
#include<stdlib.h>
int fac(int n)
{
        int y;
        if(n==0 || n==1)
            y=1;
         else
          y=n*fac(n-1);
         return y;
}
int main()
{
        int n, x;
        n=5;
        x=fac(n);
        printf("%d\n",x);
        return 0;
}
```

Fig. 4. C program of recursively calculating n!

```
@ILT+5(?fac@@YAHH@Z):
0040100A   jmp          fac (00401020)
3:     int fac(int n)
4:     {
00401020   push         ebp
00401021   mov          ebp,esp
00401023   sub          esp,44h
00401026   push         ebx
00401027   push         esi
00401028   push         edi
00401029   lea          edi,[ebp-44h]
0040102C   mov          ecx,11h
00401031   mov          eax,0CCCCCCCCh
00401036   rep stos     dword ptr [edi]
5:     int y;
6:                if(n==0 || n==1)
00401038   cmp          dword ptr [ebp+8],0
0040103C   je           fac+24h (00401044)
0040103E   cmp          dword ptr [ebp+8],1
00401042   jne          fac+2Dh (0040104d)
7:                    y=1;
00401044   mov          dword ptr [ebp-4],1
8:                 else
0040104B   jmp          fac+45h (00401065)
9:                y=n*fac(n-1);
0040104D   mov          eax,dword ptr [ebp+8]
00401050   sub          eax,1
00401053   push         eax
00401054   call         @ILT+5(fac) (0040100a)
00401059   add          esp,4
0040105C   mov          ecx,dword ptr [ebp+8]
0040105F   imul         ecx,eax
00401062   mov          dword ptr [ebp-4],ecx
10:                return y;
00401065   mov          eax,dword ptr [ebp-4]
11:    }
```

Fig. 5. The assembly language code of C program in Fig. 4

Through this case teaching, students learn activation record organization of recursive process, and implementation techniques of recursive process.

Consider the recursive implementation of Edclid's algorithm to compute the greatest common divisor of two nonnegative integers, whose C program is shown as Fig. 6.

Suppose the user inputs the values 15 and 10 to this program, so that main initially makes the call **gcd** (15, 10). This call results in a second, recursive call **gcd** (10, 5) (since $15\% \ 10 = 5$), and this results in third call **gcd** (5, 0) (since $10\% \ 5 = 0$), which then returns the value 5. During the third call the runtime environment may be visualized in Fig. 7. Note how each call to **gcd** adds a new activation record of exactly the same size to the top of the stack, and in each new activation record, the control link points to the control link of the previous activation record. Note also that **fp** points to control link of the current activation record, so on the next call the current **fp** becomes the control link of the next activation record.

```
#include "stdio.h"
int i, j;
int gcd(int a, int b) {
    if(b == 0)
        return a;
    else
        return gcd(b, a % b);
}
int main() {
    scanf("%d %d", &i, &j);
    printf("%d\n", gcd(i, j));
    return 0;
}
```

Fig. 6. C program of recursive implementation of Edclid's algorithm

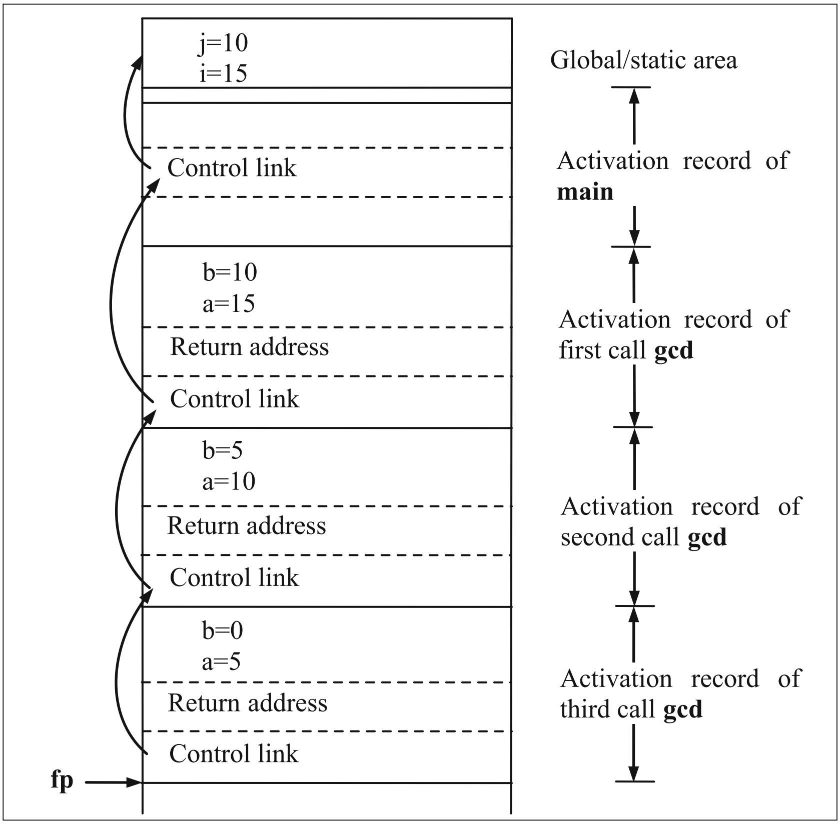

Fig. 7. Stack-based environment for C program of Edclid's algorithm

After the final call to **gcd**, each of the activations is removed in turn from the stack, so that when the **printf** statement is executed in **main**, only the activation record for **mian** and the global/static area remain in the environment. The activation record of main contains information that is used to transfer control back to the operation system.

We also students to generate assembly language code from C language program in Fig. 6 by using debug tool for C++ development environment. The assembly language code is shown in Fig. 8.

```
00401005   jmp          gcd (00401020)
@ILT+5(_main):
0040100A   jmp          main (00401080)
3:     int gcd(int a, int b) {
00401020   push         ebp
00401021   mov          ebp,esp
00401023   sub          esp,40h
00401026   push         ebx
00401027   push         esi
00401028   push         edi
00401029   lea          edi,[ebp-40h]
0040102C   mov          ecx,10h
00401031   mov          eax,0CCCCCCCCh
00401036   rep stos     dword ptr [edi]
4:         if(b == 0)
00401038   cmp          dword ptr [ebp+0Ch],0
0040103C   jne          gcd+23h (00401043)
5:             return a;
0040103E   mov          eax,dword ptr [ebp+8]
00401041   jmp          gcd+37h (00401057)
6:         else
7:             return gcd(b, a % b);
00401043   mov          eax,dword ptr [ebp+8]
00401046   cdq
00401047   idiv         eax,dword ptr [ebp+0Ch]
0040104A   push         edx
0040104B   mov          eax,dword ptr [ebp+0Ch]
0040104E   push         eax
0040104F   call         @ILT+0(gcd) (00401005)
00401054   add          esp,8
8:     }
```

Fig. 8. The assembly language code of C program in Fig. 6

Through this case teaching, students can learn stack-based environment of C program, and implementation techniques of activation record organization.

3 Assessment

In this paper, the effectiveness of approach for teaching runtime environments in a compiler construction course according to the students' feedback, students' performance, compiler project developed by students, and students' final grades.

We complete the questionnaire of ten questions on 90 students. The ten questions are shown as Table 3. The purpose of the survey is to evaluate whether students believe that the approach for teaching runtime environments in this paper help to understand the concept of running environment and the implementation of compiler, and improve their software engineering skills. The survey also asked the students if they think that the practice of developing compilers could enhance their abilities related to other subjects.

Table 3. Questionnaire results

Question	Yes	No
1. Is it difficult to understand how the compiler works?	75%	25%
2. Was this approach for teaching runtime environments of any help to understand the concept of running environment?	91%	9%
3. Was this approach for teaching runtime environments of any help to understand the implementation of compiler?	90%	10%
4. Was the debug tool important for a better understanding of compilers?	80%	20%
5. Are you interested in learning compiler construction in the past?	70%	30%
6. Are you interested in learning compiler construction now?	80%	20%
7. Do you think that you understanding runtime environment of compilers now?	85%	15%
8. Do you think you know the implementation techniques of activation record now?	83%	17%
9. Do think that the development of a compiler is a good practice to improve programming skills?	81%	19%
10. Do you think you that the practice of developing compilers could enhance their abilities related to other subjects?	75%	25%

It can be found from Table 3 that most students believe that the teaching approach of runtime environment proposed in this paper is helpful to understand the basic concept of runtime environment, master the method of object code accessing data objects, the implementation of compilers, and provide good practice for improving their programming skills.

The effective evaluation of the teaching approach for teaching runtime environments proposed in this paper is to compare the students' final grades with the results of previous courses. In 2020, the approach presented in this paper was introduced into compiler construction course. The student passing rate and average final grades from 2018 to 2021 are shown in Table 4.

As Table 4 shows, student pass rate has been gradually increased (from 74.6 to 92.6). These results may indicate that the approach described in this paper is an adequate mechanism to teach runtime environment in compiler construction course. The improvement of the pass rates and grades of students may be a result of a better comprehension of concepts.

Table 4. Evaluation of student performance from 2018 to 2021

Year of study	Student pass rate (%)	Average final grades (0–100)
2018	72.3	72.6
2019	73.6	73.3
2020	87.4	80.2
2021	92.6	81.4

4 Conclusion

A compiler is a large software system, with many internal components and algorithms and complex interactions between them. Compiler construction course is a very important and complex course in computer science. The study of compiler construction is a practical exercise in software engineering. Many theories, concepts, principles and software development techniques support the process of compiler construction.

In this paper, an effective approach for teaching runtime environments in a compiler construction course is presented. The authors' experience with using debug tool for C++ development environment for teaching runtime environments is described in a compiler construction course. First, concepts such as activation records, control link, access link, and pointer to the current activation are introduced to the students. Then, we show the implementation techniques of activation records and data access method the target computer by using debug tool for C++ development environment on C language programs.

The approach proposed in this paper is applied in the compiler construction course, which deepens students' understanding of programming language, and cultivates students' abstract thinking, logical derivation and generalization ability. This approach method also helps to improve their programming skills.

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On College Students' Satisfaction with Flipped Classroom in China in the Normalized Epidemic Era

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Abstract. In order to improve the teaching methods of flipped classroom and achieve a better teaching effect especially in normalized epidemic era, we investigate the key factors affecting college students' satisfaction with flipped classroom from the perspective of students. Through factor analysis and variance analysis, it can be found that the two most critical factors affecting students' overall satisfaction with flipped classroom are students' attitude and evaluation mechanism, furthermore, students of different genders and grades have different satisfaction with flipped classroom. This paper also conducted interviews with ten college students to deeply understand their attitudes and suggestions of flipped classroom, and put forward some suggestions for improving flipped classroom from the perspective of students.

Keywords: satisfaction analysis · flipped classroom · college students · student attitude · evaluation mechanism

1 Introduction

"Flipped classroom" refers to the realignment of time in and out of the classroom to put learning decisions in the hands of students. In this kind of teaching mode, the student needs to autonomously learn the new curriculum before class, the teacher is no longer be a knowledge speaker to transfer the curriculum knowledge but gives professional comments and answers students' questions in the class. Its idea is to turn teacher-centered into student-centered study and emphasizing the reversal of teaching subject and object [1]. In other words, teachers should change the traditional teaching and learning, pay more attention to students' independent learning, and emphasize the internalization process of knowledge [2]. Exploration of the teaching mode and application effect of flipped classroom results show that flipped classroom has been well applied in college teaching in China [3]. Since flipped classroom is a concept introduced abroad, scholars in China have put forward their own opinions on the localization [4] and teaching application model of flipped classroom. Then, according to the teaching characteristics of different courses, the application models of flipped classroom for different courses are put forward. However, researches on flipped classroom are mostly investigated from teacher's

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opinion instead of from the students', resulting the expected practice effect was not achieved.

In the first half of 2020, the sudden OUTBREAK of COVID-19 seriously affected normal teaching plans. In order to implement the "Guidelines on Organizing and Managing Online Teaching in Colleges and Universities during the Epidemic Prevention and Control period" issued by the Ministry of Education (No. 2 of the Ministry of Education) [5], and to minimize the impact of the epidemic on education while ensuring the safety and health of teachers and students, many colleges and universities have carried out online teaching, including video recording, online live broadcasting and mixed teaching [6]. Nowadays, which called "normalized epidemic prevention and control era", the flipped classroom has achieved rapid development after general online teaching practice.

The investigation shows that the practice of flipped classroom in China has not achieved ideal effect [7], and the mode of the flipped classroom is still in explorer. To help improving the teaching method of flipped classroom, we collect students' feedback on the use of flipped classroom from the perspective of students to find out the driving factors that affect students' satisfaction with flipped classroom, to betterly accept this new teaching method.

2 Preparation of Questionnaire

The core part of questionnaire include seven parts which are usage situation, the comments and proposals, the overall satisfaction, the teaching tools accessibility, the interactivity, the students' attitude to flipped class room, and evaluation mechanism, each part corresponding to a variable of the measurement. The first two parts are organized in the form of traditional question choices, and the last five items are measured with five-level Likert scales.

The factors may influence the teaching effect of flipped classroom in questionnaire involves four variables. By collecting the class experience of college students, the paper verify whether the four variables can really affect the application effect of flipped classroom for college students. The four variables are explained as:

2.1 Evaluation Mechanism

College students' satisfaction with the scoring mechanism of flipped classroom. Fair and reasonable course evaluation mechanism can increase students' learning motivation to a certain extent and unreasonable evaluation mechanism will not only lose students' interest in learning the course, but also affect students' learning effect of the course.

2.2 Usability of Teaching Tools

The usability of teaching tools in flipped classroom can influence the difficulty of students mastering the use of the teaching platform to obtain required learning resources and complete learning tasks in time.

2.3 Classroom Interaction

Classroom interaction include the interaction of students with students and students with teachers. Fully using of classroom interaction activities can improve students' learning enthusiasm and participation to understand classroom content better, and to improve their learning effect.

2.4 Students' Attitude Towards Flipped Classroom

It requires students having a higher learning autonomy in the flipped classroom, so the learning attitude influence the final study effect to a certain extent. Only students with good attitudes can finish the learning tasks and participate actively in classroom interaction.

3 Survey Implementation

The questionnaire was distributed to college students through "the Questionnaire Star" platform, 172 questionnaires were recovered in which 148 questionnaires is valid. There are 56 boys and 92 girls answer the questions and freshmen accounted for 39.8%, sophomores 37.8%, juniors 16.2% and seniors 6.2% in angle of view grade. In order to understand the real thoughts of college students to flipped classroom, we conducted in-depth interviews with 10 college students to find reasonable suggestions for improving flipped classroom teaching from the perspective of students.

3.1 Reliability and Validity Test

The Reliability Analysis

According to descriptive statistical analysis of each measurement variable, the average value of each measurement variable was bigger than 3 which indicating that college students' overall use of flipped classroom is good. In addition, by comparing the average value of each variable, it can be seen that college students have the highest satisfaction with the usability of teaching tools, which the average value is more than 4, indicating that college students can skillfully use flipped classroom teaching tools with their current skills and skillfully obtain required learning resources through the teaching platform. The most unsatisfactory factor in the statistical data is students' attitudes, indicating that students' learning attitude towards flipped classroom needs to be improved. Statistical analysis of Cronbach's Alpha by SPSS showed that Cronbach's Alpha was between 0.748 and 0.914, as shown in Table 1, indicating that the questionnaire has high reliability.

The Reliability Analysis

KMO and Bartlrtt's test was used to test the validity for all the subjective items of the questionnaire. In the output results, the quantity of KMO sampling suitability was 0.843 which greater than 0.7, as shown in Table 2, indicating that the questionnaire has good structural validity. In Bartlett's spherical test, P = 0.000 which is less than 0.05, indicating that the questionnaire has high validity and can be used for factor analysis.

Table 1. Reliability Analysis

Variable	Item	N	The Average	The Standard Deviation	Cronbach's Alpha
Overall satisfaction	O1	148	3.24	1.14	0.914
	O2	148	3.13	1.18	
Usability of teaching tools	E1	148	4.27	0.88	0.820
	E2	148	4.02	0.95	
Classroom interaction	I1	148	3.47	1.06	0.837
	I2	148	3.45	1.23	
	I3	148	3.77	1.14	
Students' attitudes	A1	148	3.33	1.20	0.748
	A2	148	3.59	1.04	
Evaluation mechanism	EVA	148	3.59	1.07	

Table 2. Validity Analysis

Test Method	Statistics	Standard Value
Kaiser-Meyer-Olkin	KMO	0.843
Bartlett's Test of Sphericity	The Approximate Chi-square	1010.364
	df	45
	Sig.	0.000

3.2 Analysis of Key Factors Improving Satisfaction with Flipped Classroom

Take the influence factors of attitudes, evaluation mechanism, teaching interaction, usability of teaching tools as the independent variables, and to take overall satisfaction as dependent variable to build stepwise regression equation to analyze which key factors that affect student's satisfaction of flipped classroom. The result is shown in Table 3. It can be seen that model 3 has the best fitting effect through the adjusted R2. Therefore, it can be seen from Table 5 that, at the significance level of 0.05, the significant factors that can affect the overall satisfaction of college students with flipped classroom are student attitudes, usability of teaching tools and evaluation mechanism.

ANOVA test was performed on the three fitted models. From Table 4, we can see that the results showed that all the three models were statistically significant, but all variables in the models were not necessarily statistically significant.

T test was performed on each coefficient in the three models shown in Table 5. It can be seen that the significance probabilities of the constant term and the three variables T are all smaller than 0.05, indicating that the coefficients of these variables are significantly different from 0, so these variables should be included in the equation as explanatory variables. It should be noted that although the parameter of the Usability of teaching

Table 3. Model Summary

Model	R	R^2	Adjusted R^2	Errors in Standard Estimates
1	0.780	0.608	0.605	0.70139[a]
2	0.797	0.635	0.630	0.67884[b]
3	0.806	0.650	0.643	0.66681[c]

[a]Predictive variables: (constant), student attitudes.
[b]Predictive variables: (constant), student attitude, teaching tool ease of use.
[c]Predictive variables: (constant), student attitude, teaching tool usability, evaluation mechanism.

Table 4. ANOVA of the Three Fitted Models

Model		Sum of Squares	Degrees of Freedom	Mean Square	F	Significant
1	Regression	111.315	1	111.315	226.271	0.000[a]
	Residual	71.825	146	0.492		
	Total	183.140	147			
2	Regression	116.321	2	58.160	126.210	0.000[b]
	Residual	66.819	145	0.461		
	Total	183.140	147			
3	Regression	119.113	3	39.704	89.296	0.000[c]
	Residual	64.027	144	0.445		
	Total	183.140	147			

Dependent variable: overall satisfaction.
[a]Predictive variables: (constant), student attitude.
[b]Predictive variables: (constant), student attitude, teaching tool ease of use.
[c]Predictive variables: (constant), student attitude, teaching tool usability, evaluation mechanism.

tools variable also passed the test, its value was negative (−0.243), which was contrary to our initial prediction and violated common sense, so it was not taken as a key factor of satisfaction.

In summary, the factors that can improve students' satisfaction with flipped classroom are students' attitude and evaluation mechanism(see Fig. 1). In order to improve students' satisfaction with flipped classroom, improvement and exploration should be carried out from these two aspects.

Table 5. Student's t Test of Regression Coefficient

Model	Unnormalized Coefficient		Normalization Coefficient	Significant
	B	Root Mean Squared Error	Beta	
1 (Constant)	0.198	0.207		0.339
Students' attitudes	0.863	0.057	0.780	0.000
2 (Constant)	0.958	0.305		0.002
Students' attitudes	0.915	0.058	0.827	0.000
Usability of teaching tools	−0.227	0.069	−0.172	0.001
3 (Constant)	0.805	0.306		0.009
Students' attitudes	0.805	0.072	0.728	0.000
Usability of teaching tools	−0.243	0.068	−0.184	0.000
Evaluation mechanism	0.167	0.067	0.161	0.013

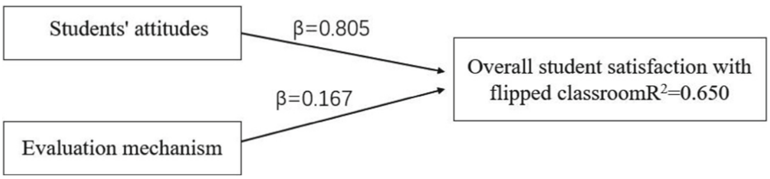

Fig. 1. Analysis results of key factors to improve students' satisfaction with flipped classroom

3.3 Demographic Analysis of Satisfaction

The Satisfaction Difference in Gender

Through the variance analysis, as shown in Table 6, the significance level of overall satisfaction of male and female college students to the flipped classroom is 0.028 which is less than 0.05, shows that there are significant differences in different gender of college students to flipped classroom.

Table 6. ANOVA by Gender

		Degrees of Freedom	F	Significant
Overall satisfaction	Between groups	1	4.912	0.028
	Within the group	146		
	Total	147		

(*continued*)

Table 6. (*continued*)

		Degrees of Freedom	F	Significant
Students' attitudes	Between groups	1	6.073	0.015
	Within the group	146		
	Total	147		
Evaluation mechanism	Between groups	1	4.241	0.041
	Within the group	146		
	Total	147		
Usability of teaching tools	Between groups	1	0.950	0.331
	Within the group	146		
	Total	147		
Classroom interaction	Between groups	1	2.069	0.152
	Within the group	146		
	Total	147		

Through descriptive statistical analysis shown in Table 7, we can see that girls' overall satisfaction with flipped classroom is significantly better than boys. From the perspective of influence factors, college students of different genders have significant differences in the two factors of student attitude and satisfaction of evaluation mechanism (at the significance level of 0.05), where female students' attitude and satisfaction of evaluation mechanism are generally higher than that of male students. In addition, there is no significant difference in the usability of teaching tools and classroom interaction between different genders, indicating that both boys and girls can skillfully use the teaching platform and basically participate in classroom interaction.

Table 7. Descriptive Analysis of Different Genders

		The Case Number	The Average	95% Confidence Interval for the Mean	
				Lower Limit	Upper Limit
Overall satisfaction	Male	56	2.9286	2.6062	3.2510
	Female	92	3.3424	3.1281	3.5567
	Total	148	3.1858	3.0045	3.3671
Students' attitudes	Male	56	3.2054	2.9247	3.4860
	Female	92	3.6196	3.4216	3.8176

(*continued*)

Table 7. (*continued*)

		The Case Number	The Average	95% Confidence Interval for the Mean	
				Lower Limit	Upper Limit
	Total	148	3.4628	3.2990	3.6267
Evaluation mechanism	Male	56	3.3571	3.0284	3.6858
	Female	92	3.7283	3.5314	3.9251
	Total	148	3.5878	3.4132	3.7625
Usability of teaching tools	Male	56	4.2321	3.9873	4.4770
	Female	92	4.0924	3.9264	4.2584
	Total	148	4.1453	4.0079	4.2826
Classroom interaction	Male	56	3.4167	3.1267	3.7067
	Female	92	3.6522	3.4683	3.8361
	Total	148	3.5631	3.4056	3.7206

The Satisfaction Difference in Grades

Through variance analysis as shown in Table 8, students of different grades have significant differences in satisfaction with flipped classroom. Through descriptive statistical analysis shown in Table 9, we can see that freshmen have the highest satisfaction with flipped classroom, followed by sophomores, juniors and seniors. There is no significant difference in the evaluation of classroom interaction among college students of different grades, but significant differences in evaluation mechanism, student's attitudes and usability of teaching tools (at the significance level of 0.05).

Table 8. ANOVA by Grade

		Degrees of Freedom	F	Significant
Overall satisfaction	Between groups	3	8.657	0.000
	Within the group	144		
	Total	147		
Students' attitudes	Between groups	3	3.760	0.012
	Within the group	144		
	Total	147		

(*continued*)

Table 8. (*continued*)

		Degrees of Freedom	F	Significant
Evaluation mechanism	Between groups	3	3.797	0.012
	Within the group	144		
	Total	147		
Usability of teaching tools	Between groups	3	2.848	0.040
	Within the group	144		
	Total	147		
Classroom interaction	Between groups	3	0.759	0.519
	Within the group	144		
	Total	147		

Table 9. Descriptive Analysis of Different Grades

		The Case Number	The Average	95% Confidence Interval for the Mean	
				Lower Limit	Upper Limit
Overall satisfaction	Freshman	59	3.5169	3.2486	3.7853
	Sophomore	56	3.3036	3.0083	3.5988
	Junior	24	2.4167	1.9868	2.8465
	Senior	9	2.3333	1.8626	2.8040
	Total	148	3.1858	3.0045	3.3671
Evaluation mechanism	Freshman	59	3.9153	3.6920	4.1385
	Sophomore	56	3.4821	3.1633	3.8010
	Junior	24	3.2083	2.7428	3.6739
	Senior	9	3.1111	2.3009	3.9214
	Total	148	3.5878	3.4132	3.7625
Usability of teaching tools	Freshman	59	4.0508	3.8460	4.2557
	Sophomore	56	4.0268	3.7735	4.2801
	Junior	24	4.5417	4.2569	4.8264
	Senior	9	4.4444	3.9201	4.9688
	Total	148	4.1453	4.0079	4.2826

(*continued*)

Table 9. (*continued*)

		The Case Number	The Average	95% Confidence Interval for the Mean	
				Lower Limit	Upper Limit
Classroom interaction	Freshman	59	3.6893	3.4436	3.9349
	Sophomore	56	3.4226	3.1421	3.7031
	Junior	24	3.5417	3.2127	3.8706
	Senior	9	3.6667	2.7978	4.5356
	Total	148	3.5631	3.4056	3.7206
Students' attitudes	Freshman	59	3.7288	3.4805	3.9771
	Sophomore	56	3.4464	3.1636	3.7292
	Junior	24	3.0417	2.6738	3.4096
	Senior	9	2.9444	2.2141	3.6748
	Total	148	3.4628	3.2990	3.6267

3.4 Summary of Student's Suggestions

In order to further understand students' ideas and find reasonable suggestions for improving flipped classroom satisfaction, ten students from different majors were selected for interview (Table 10).

Table 10. Interview Questions

Aspect	Questions
Usage Situation	1. Are there many flipped classroom classes in schools? 2. Does the use of flipped classroom help your learning?
Attitudes	1. How do you understand flipped classroom? 2. Do you like the flipped classroom?
Improvement Suggestions	1. What shortcomings of flipped classroom do you think? 2. What the main factors that affect the teaching result of flipped classroom do you think? 3. What aspects of flipped classroom should be optimized to enhance students' recognition? 4. What are your suggestions for the development of flipped classroom? 5. What do you think should be done to make flipped classroom more attractive to college students?

Usage Situation
Two interviewees represented only a tiny part of their course using flipped classroom teaching mode, three of them represented nearly a third of the course using flipped classroom teaching mode, and five interviewees represented nearly half of the course using flipped classroom teaching mode, all the interviewees said only a small number of the flipped course help to their own learning, and these courses are generally considered to be more important by students.

Attitudes
Most interviewees' understanding of flipped classroom is limited to courses that combine online and offline teaching, and three interviewees even think flipped classroom is online class. It can be seen that although the school actively advocates flipped classroom teaching, students do not really understand flipped classroom, which is not conducive to the implementation of flipped classroom. In addition, 80% of the interviewees said that they like and are willing to accept the teaching reform of flipped classroom, indicating that flipped classroom has relatively high acceptance in China.

Improvement Suggestions
When it comes to improvement suggestions, all the interviewees agreed that Students' initiative in learning is the key to the implementation of flipped classroom. Since the teaching aim of flipped classroom is to give the initiative of teaching to students, teachers should not set up the mandatory learning tasks and rigid evaluation mechanism, and should focus on how to improve the quality of courses to arouse students' interest in learning, so that students are willing to take the initiative to learn. Some of them suggested that teachers should add some interesting thoughts or short jokes in the course to stimulate students' interest in learning, while others suggested that different kinds of interactive teaching methods should be added so that every student could actively participate in the class and improve learning efficiency.

Through the interview, we found that most of the students think the part of the autonomic learning before class does not put into effect well, and interviewees mentioned suggestions mostly focus on autonomous learning before class, which shows the importance of autonomous learning, so that teachers should improve the quality of recorded courses and set more interactive forms to mobilize students' learning interest.

4 Conclusion and Suggestions

It is found that flipped classroom has ushered a rapid development in the normalized epidemic era in China. The attitude of students is the most critical factor affecting college students' satisfaction with flipped classroom, and the evaluation mechanism of classroom also has an impact. College students of different genders and grades have different attitudes towards flipped classroom, and their overall satisfaction with flipped classroom is different.

4.1 Change Students' Attitudes Through Explaining the Teaching Mode of Flipped Classroom

The survey result shows that most students do not attach much importance to flipped classroom courses and have a superficial understanding of flipped classroom. They think flipped classroom is just a simple online course and subconsciously think the recorded courses are not that important, which leads to serious perfunctory learning before class.

In addition, due to the "flip" teaching concept of flipped classroom, the initiative of learning is mainly in the hands of students, while the "letting go" of teachers gives many students a wrong idea of "this course is not important", which leads to students' not serious treatment of the course and the learning efficiency is lower than normal class. In view of this, teachers should explain the teaching concept, teaching methods, teaching objectives and course evaluation methods of flipped classroom to students at the beginning of courses, so that students can treat flipped classroom courses with a correct attitude. Besides, teachers can also set up a variety of interesting tasks or suspense to let the students fulling expectation and confidence to the course.

4.2 Improve and Make Clear Course Evaluation Mechanism

Flipped classroom pays more attention to the improvement of students' comprehensive ability than ordinary teaching mode. So the evaluation standard cannot be measured only by examination performance [8]. The questionnaire analysis results show that the evaluation mechanism plays a positive impact in promoting the teaching satisfaction, indicating that reasonable evaluation criteria play an important role in flipped classroom.

However, according to the interview, some students expressed that the evaluation mechanism of flipped classroom is not perfect and the evaluation standard is not clear, that is, there is no clear and reasonable evaluation standard for each step of flipped classroom teaching, which leads to students' slackness in some teaching steps and ultimately affects the teaching effect. So teachers should clarify the evaluation rules and formulate reasonable and comprehensive evaluation standards at the beginning of the curriculum.

In addition, evaluation measures should not only focus on students' scores, but also reflect students' comprehensive quality. Teachers can adopt multiple evaluation methods, such as learning portfolio evaluation, project works evaluation, student evaluation with each other, group evaluation with each other, etc., and increase the number of usual quizzes and other formative evaluation. The evaluation can be combined with computer test, written test, homework and online learning data.

4.3 Improve the Quality of Online Courses

Learning videos is an important part of flipped classroom in e-learning [9]. Since the teacher is not facing the students but the machine when recording the video, it is difficult to observe the students' real reaction in the course of teaching. When students watch videos, due to the lack of face-to-face emotional communication between teachers and students, the learning process becomes cold and impersonal.

At the same time, Recoding learning videos requires a large amount of time and economic investment, so it is difficult to produce exquisite teaching videos under the condition of insufficient funds and time. This also leads to students' declining interest and low efficiency in autonomous e-learning, leading to negative attitudes towards flipped classroom. The survey also shows that students expect more interesting and higher quality course videos as a powerful tool for pre-preparation, so improving the quality of video courses is an important way to improve students' attitude towards flipped classroom. The higher the quality of flipped classroom course videos, the better attitudes of students towards the course, and thus greater interest and confidence in learning the course.

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Research on the Reform and Construction of Computer Basic Courses Based on Big Data

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Abstract. The era of big data has come and is quietly changing the traditional industry. How to use big data technology to promote the development and reform of the education industry and actively explore the integration and innovative application of big data and education is an urgent problem to be solved in the development of education in the new era. Based on big data technology, this paper designs educational reform from many aspects, including teaching methods, personalized education and intelligent education. The research on Curriculum Teaching Reform under the background of big data is of great significance, which provides a reference for the reform and construction of computer basic courses in local colleges and universities, and points out the direction for the optimization and upgrading of existing teaching modes.

Keywords: Curriculum reform · Curriculum construction · Basic computer courses · Big data

1 Introduction

Today, in the era of big data, the data scale of all walks of life is gradually huge, the data surge, the concept of big data came into being, and the application of big data is gradually changing all traditional industries. Actively exploring the integration and innovative application of big data and education is an urgent problem to be solved in the development of education in the new era. At present, the application of big data in education in foreign countries far exceeds that in China, but so far there is no good intelligent education system to be popularized and applied. Various online teaching resources are rich, but lack of connection and integration. If these resources can be effectively integrated and applied, the traditional education and teaching mode will be changed and organically integrated with the existing education and teaching mode according to the advantages of these courses, Study the curriculum teaching reform under the background of big data.

In terms of education, China has also set off a new wave of educational informatization. Under the background of the big data era, domestic colleges and universities have made great efforts to build popular flipped classroom, MOOC (MOOC) and micro class resources in western countries [1]. Although these resources are relatively abundant now,

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there is no significant change compared with the existing teaching mode, let alone the intellectualization of teaching, and the quality and efficiency of education and teaching have not been improved. The reason is our system and ideological problems. The majority of teachers and education managers are unwilling to accept the changes of teachers' functions and teaching methods, thinking that the education reform based on big data will lay off teachers, and are even less willing to spend a lot of time and money on this reform.

Learning analysis is a new concept derived from the combination of big data and education. It uses big data technology to analyze students' learning behavior, test scores, career planning and other important information. Learning analysis in education should deeply excavate valuable learning information from multiple dimensions (including learning tendency, learning process, interaction and cooperation, learning attitude, learning ability, etc.), evaluate students' learning with big data thinking and technology [2], reveal the hidden learning information and make visual display. In the United States, many of these data have been stored by government agencies such as the National Center for Education Statistics for statistics and intelligent analysis. Big data has been applied to public education in the United States and has become an important force in teaching reform. A $200 million big data + education plan in public education was implemented in 2012.

2 Main Objectives of the Study

Education reform based on big data can be reformed from many aspects, including teaching methods, personalized education and intelligent education, but ordinary schools, especially local colleges and universities, have hardly started. Therefore, the research on Curriculum Reform under the background of big data is of great significance. Here, the research is mainly carried out from the following aspects:

(1) Use big data to promote students' personalized learning. Make full use of academic diagnosis data to analyze attribution, make use of students' individual situation, and rely on various carriers such as mobile learning terminal, digital classroom, learning space and platform to promote the reform of students' personalized learning methods, such as pushing students' personalized chemical industry evaluation results, personalized production industry and personalized learning resources; Driven by course teachers, let students enter the "Digital Classroom" with learning tasks for centralized learning in various ways such as online practice, e-reading and foreign language interactive learning, so as to collect the data of students' learning process, push personalized chemistry learning content and promote students' autonomous learning through the big data teaching system [3].
(2) Use big data to promote the improvement of classroom teaching level. Make full use of students' learning process data, identify teaching weaknesses, promote teachers' effective research, carry out teaching with a targeted aim, promote teachers' accurate force in the process of classroom teaching, and improve the effectiveness and quality of teaching [4].

(3) Use big data to automatically guide students' autonomous learning. Make full use of the knowledge system of the course group, build a knowledge map and relationship, recommend learning contents, guide students to carry out problem driven learning, modular learning, theme based learning and project driven learning, and use big data analysis intelligence to give a variety of solutions to problems and knowledge that needs to be supplemented, so as to guide students to study independently and self-help [5].

(4) Use big data to control the dynamics of students' thoughts and behaviors. In the era of big data, a large amount of data is needed. In theory, students' relevant data can be collected through multiple sets of teaching management systems, such as students' personal information, academic performance, ability tendency, specialties and hobbies, personality characteristics, and even various learning process data, such as social networking, log information, practice duration, wrong questions, learning process records and so on. Based on these data, we can further analyze and deeply mine its key information, timely grasp students' public opinion, learning attitude and difficulties on a hot issue, accurately judge and predict their attitude or behavior tendency, and make correct handling suggestions. We should take correct measures to avoid the phenomenon of school weariness or truancy and avoid it in time [6].

3 Content of Education Reform Based on Big Data

(1) Construction of curriculum teaching system: when building a curriculum teaching system based on big data, we must closely focus on the talent training objectives, according to the needs of enterprises for talents, combined with the blue book big data + education, carefully sort out and integrate the curriculum teaching content, build a modular, hierarchical and clue Curriculum teaching system based on big data, and realize personalized and differentiated teaching. According to students' learning characteristics, recommend relevant knowledge content, orderly guide students' autonomous learning, improve learning efficiency and cultivate students' autonomous learning ability. Adopt the method of "combining inside and outside the classroom and complementing various forms", strengthen practical teaching links at multiple levels and in an all-round way, ensure the effectiveness of curriculum practical teaching and form a complete practical teaching system. In accordance with the principle of cultivating practical ability and innovation ability step by step, experiment, practice, training and curriculum design will be taken as an organic whole and unified planning. The teaching management system based on big data will guide students' learning in an orderly manner, adopt the mode of project driven and problem oriented, and the big data system will automatically push relevant learning contents and micro class videos for students to learn, so as to avoid students' blindness and confusion, Through the micro class video, students can restore the classroom teaching situation after class, review relevant knowledge and learn forgotten content, so as to improve the teaching quality.

(2) Reform of curriculum teaching mode: under the guidance of teachers and big data analysis system, carry out theoretical teaching and practical teaching with project

cases as the bedding, so that students can understand the specific objectives of practice and practice specific training contents. The open “project driven” practical teaching mode can fully integrate the training modes of “integration inside and outside school”, “integration inside and outside class” and “integration of theory and practice”. The “problem oriented” theoretical teaching mode takes problem-solving as the main line, and publishes pre class problems 2–3 days in advance. The big data analysis system and teachers recommend rich learning resources, including knowledge content, classic cases and micro class videos. Students are required to fully learn relevant contents before class. In case of problems, they can find solutions through the big data analysis system or course discussion group, and teachers and other students can reply to questions or tips. In order to reduce manual labor, the big data analysis system designed in this project will have the function of automatically answering students’ questions. For problems, through big data analysis, the big data system will automatically prompt possible solutions. At present, this function has been implemented in many systems such as Taobao and JD. This project will apply the automatic question and answer function based on big data to teaching activities, which will promote the intellectualization and automation of course teaching. For students who do not prepare and prepare before class, their situation will be recorded in the course process assessment record, which will directly affect the course assessment results. Necessary supervision and requirements are effective means to ensure the teaching effect.

(3) Reform of course teaching methods: Based on the idea of “project driven and problem oriented”, carry out course teaching, disclose problems and projects in advance, and let students learn relevant contents first. The classroom will be an important place to solve and discuss problems, and the basic course knowledge requires students to complete before class. In order to ensure that students can learn relevant knowledge in advance and complete it effectively, it is necessary to provide students with rich materials and complete online tests. The materials include relevant knowledge content, PPT courseware, typical cases and solution process, micro class videos of relevant knowledge, micro class videos of answers to relevant questions, etc. these resources can be obtained from more than 4000 mu courses or high-quality courses websites and college course groups across the country, During the implementation of the project, it is also necessary to build some resources, integrate these resources, form a complete knowledge system, rich and diverse learning resources, and have a learning environment in which the big data analysis system can automatically accurately and effectively recommend resources and automatically answer questions, and teachers can effectively discuss and solve problems in class.

(4) Reform of course assessment method: the method of determining course scores from the current final examination is changed to the process evaluation method of paying attention to students’ learning. Students must complete the specified course learning hours, and each class is arranged with pre class questions and relevant learning resources, post class tests and assignments. Before class study and after class test, students can view the learning records and test results in real time. After class homework requires students to submit within the specified time. The system and teachers timely correct the homework, and publish the results online for

students to view. For unqualified homework, students are required to redo. Students' course scores are summarized from the learning situation and achievements of all stages, so students must pay attention to and take seriously every study, test and homework. During the implementation of the project, the existing 8 sets of teaching management systems will be improved, so that they can record the whole process of students' learning and participating in the test, record the length of learning a certain knowledge point and the length of answering a test question, timely predict students' existing problems and recommend relevant contents and learning materials for their learning in combination with the results of relevant knowledge, so as to improve students' learning efficiency and accuracy. At the same time, with the help of big data and big data analysis, we can control the dynamics of students' thoughts and behavior and learning attitude, and take countermeasures in time to avoid the phenomenon that we know that the student has been left behind for a long time when we find that the final grade is unqualified in the traditional teaching process. At that time, there is no way to make up for it, wasting students' academic time and missing learning opportunities.

(5) Reform of learning process management: the teaching management system based on big data comprehensively analyzes the process data of students' learning, grasps students' learning situation and learning attitude, excavates students' learning habits and characteristics, timely adjusts the course difficulty and teaching speed, recommends personalized knowledge content according to students' characteristics, and highlights the cultivation of personalized and differentiated talents. The course results shall be subject to process assessment, reduce the proportion of final results, implement random test paper formation, allow multiple exercises and simulations, and improve the passing standard of final results. Similar to the first test of driver's license, 90 points are qualified, and the specific passing standard can be set according to the specific situation. The teaching management system based on big data adopts the point system management, and students will get certain points every time they complete learning tasks, exercises, tests and reply to other students' questions. You will get different points every day. The more days you study continuously, the more points you get every day. If you interrupt your study one day, you will be rewarded with points every day from the lowest point. Each test score and ranking will also get different points. The points rules involve the whole learning process of students. Students are encouraged to study after class, on weekends and holidays, and the points will be 2–5 times as much as usual. For example, it can be used to obtain the answers to the questions and classic questions in the book and video learning system. The integral system has been implemented in the program design course for many years, and the effect is very good. It is found that the integral system has greatly promoted students' learning, gave full play to students' learning initiative, initiative and consciousness, and improved the course performance.

4 Content of Education Reform Based on Big Data

Guided by the blue book of big data + education, the idea of big data + education and curriculum teaching reform are run through the research process. Through the functional upgrading of the existing 8 sets of web-based teaching management systems, they have the data basis of big data analysis and the educational function of design, formulate the curriculum teaching system under the background of big data, and select the course of advanced language programming for implementation for one year, Analyze the implementation results, summarize the experience and lessons, put forward and implement improvement measures, and test the implementation effect of the project. After the implementation effect is satisfactory, it is gradually extended to other courses for implementation.

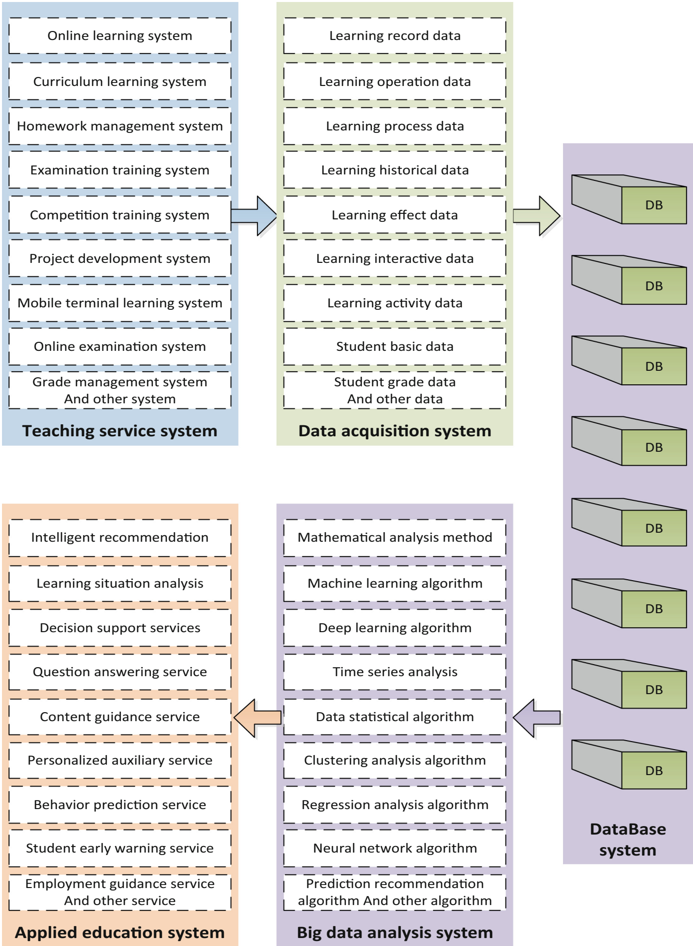

Fig. 1. Structure and function design block diagram of education system based on big data

The technical route is divided into four aspects:

(1) The function design is based on the education system structure based on big data (as shown in Fig. 1).

(2) Carry out teaching reform with the application model of curriculum teaching system based on big data (as shown in Fig. 2).
(3) The application model of course learning system based on big data (as shown in Fig. 3) is used to guide students' autonomous learning.

5 Summary

Based on Marx's practical human theory and Gardner's multiple intelligences theory, this teaching reform design puts forward the method system of "personalized teaching" supported by information technology. Based on Piaget's cognitive schema theory, schweiler's cognitive load theory and PBL project-based teaching method, it puts forward the concept of "project-based education" and the way of curriculum teaching implementation of "focusing on students' ability construction", It reflects the advanced theoretical guiding characteristics of the project. Using modern information technologies such as big data, big data and mobile Internet, we have independently developed a number of relevant personalized teaching and thematic project education teaching management systems, and established an automatic implementation scheme for attendance, homework, resource sharing, teaching feedback, classroom interaction, personalized chemical situation monitoring, and topic selection, review, evaluation and feedback in project management, It embodies the advanced characteristics of the project that has deep integration of modern information technology. Adopt big data and big data analysis technology to realize data-driven teaching and learning decision-making, and build a curriculum teaching system and implementation scheme based on big data online learning platform, which reflects the rigorous characteristics of the project speaking with data in personalized education decision-making.

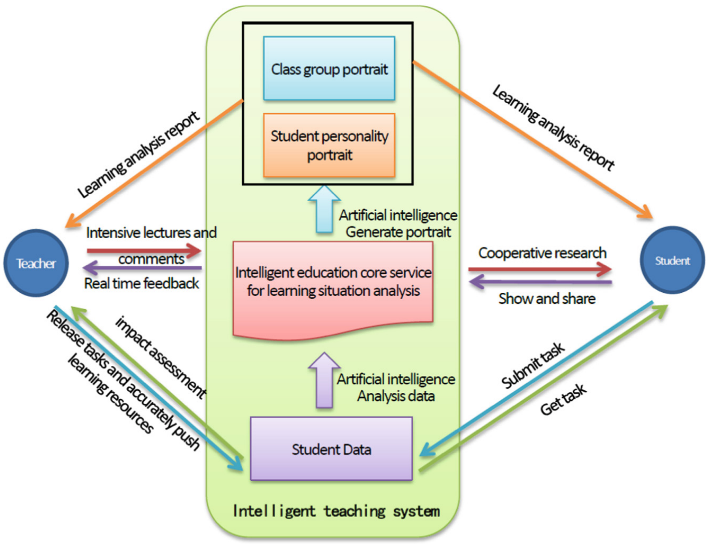

Fig. 2. Application model diagram of course teaching system based on big data

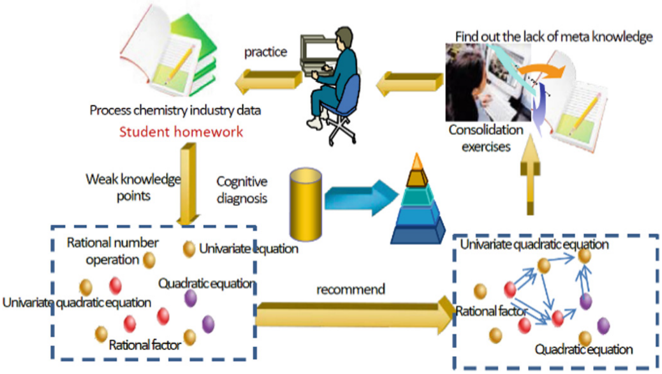

Fig. 3. Application model diagram of course learning system based on big data

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Exploration and Practice of Computer Fundamentals Course Based on Computational Thinking Competency Improvement

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Abstract. The computer fundamentals course is an important course in computer education in higher education. It serves the role of cultivating students' computational thinking and being able to use information technology to solve complex computational problems in various majors. However, the original objectives and teaching content of the course did not meet the needs of the new AI era, did not integrate with the disciplines, and the teaching method did not reflect the shortcomings of student-centered. This paper constructs a computational thinking hierarchical competency improvement model of, and adopts the OBE method to reverse the teaching content, teaching methods and evaluation methods. The teaching reform achieved good results in practical teaching and learning. Finally, this paper discusses the inefficient of teaching reform and the direction of improvement in the future.

Keywords: Computer fundamentals course · Artificial intelligence · Case method · OBE · Computational thinking

1 Introduction

With the continuous development of technologies such as Internet, big data, cloud computing and Internet of things, Artificial Intelligence (AI) is triggering scientific breakthroughs that can have a knock-on effect. The advent of the new AI era will spawn a number of disruptive technologies, lead a new round of scientific and technological revolution and industrial development, and have a huge impact on future social economy, life and other aspects. The ability of AI in big data-driven visual analysis, natural language understanding and speech recognition has been improved rapidly. In 2018, the Ministry of Education of China issued the "Innovative Action Plan for Artificial Intelligence in Colleges and Universities", putting forward colleges and universities should take aim at the world's frontier and give play to their own advantages to support China's AI development strategy [1, 2]. AI is a trans-disciplinary field. Colleges and universities should set up new curriculum related to AI or reform the teaching contents to strengthen AI capacities, explore the problem-oriented interdisciplinary talent cultivation model and

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improve students' innovation and practical ability. Every discipline needs to explore the talent training mode of "Artificial Intelligent + X". In 2019, the "Six Excellence and One Top-notch" plan 2.0 has put forward to comprehensively promote the construction of "new engineering, new liberal arts, new medical science, and new agricultural science". The "four new" disciplines are characterized by cross-integration, and they are all related to new technologies represented by big data and AI. The working paper which was produced by UNESCO's Education Sector in 2019 described Computational Thinking (CT) has emerged as one of the key competencies to enable learners to thrive in an AI-powered society [3].

University computer fundamentals course is a compulsory general education course for freshmen. It plays an important role in cultivating students' information literacy in colleges and universities. However, at this stage, there are some problems in the teaching content and teaching methods of computer fundamentals course in universities, which cannot meet the needs of cultivating compound talent of the new AI era. What students learn does not support the information literacy required to solve problems in their area of expertise. CT abilities and practical problem-solving skills are lacking. Based on the new form and connotation of CT in the AI era, this paper proposes a CT hierarchical competency improvement model. Based on this model, a systematic teaching reform plan and a corresponding blended teaching method are given, a corresponding evaluation mechanism is designed for different levels of CT ability, and the effect of reform practice is summarized.

2 Status Analysis

The main problems of computer fundamentals course in universities are as follows:

First, the teaching content of computer fundamentals course is mainly to understand the composition of computer system, master the operation of office software or some application software. Although some majors teaching programming language, students mostly learn grammar details and understand classic algorithms. The teaching content does not involve new technologies and their applications. It has no AI-related content, such as computer vision, robotics. Moreover, the course content lacks awareness of the overall development context and future trend of computer and information technology.

With the development of technology, all majors need students to have CT, and the ability to predict, simulate and solve complex engineering problems by using information technology. But at this stage, the positioning of information technology courses, the role of professional support is not reflected. The cultivation of CT is not enough to meet the needs of cultivating interdisciplinary and innovative talents.

Second, the course content does not involved the development and application of information technology in various disciplines, and lacks an introduction to the frontiers and research hotspots of the development of information technology in various disciplines, such as computational jurisprudence, digital humanities, computational linguistics, econometrics, computational chemistry, and bioinformatics. Most of the cases used in teaching are simple mathematical problem solving and classical algorithm implementation. There is a lack of cases integrating with their majors. It cannot meet the needs of the construction of new engineering, new liberal arts, new medical science, and new agricultural science. It does not reflect the needs of integrating information technology into discipline construction. It can't meet the needs of promoting multidisciplinary crossover and deep integration, and promoting the acquisition of competencies required by and AI-powered society.

Third, the course teaching emphasizes knowledge and ignores practical ability. The content of programming language courses for non-computes majors mainly emphasizes grammar and ignore engineering project practice. The teaching process emphasizes lectures and neglects practice and training. Many students are lack of understanding of the working principle of computer, and have insufficient ability to solve complex problems and insufficient engineering ability training.

Students do not have the CT for problem decomposition, pattern recognition, abstraction, and algorithmic design and programming. In addition, the course has more teaching content and less class hours. It corresponds to the first three layers of Bloom's taxonomy of educational objectives: knowledge, comprehension and application, mostly knowledge and comprehension [4]. The teaching effect of the course only enables students to acquire a general ability to use computers, focusing on basic information knowledge and basic operating skills.

Fourth, As the first information course in University, many students have weak foundation or no foundation. In a questionnaire survey of 721 freshmen in fall semester 2020, 580 people have no programming foundation. Accounted for 80.44% of the total number of people surveyed, which is shown in Fig. 1. Even many students are not familiar with the basic operation of computer. The basis of information technology is different, and the understanding of computer is different, especially the liberal arts students have no concept of computational thinking. Many students are afraid of programming.

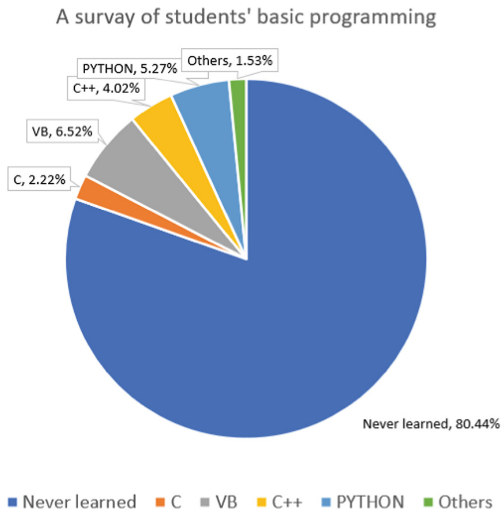

Fig. 1. A survey of freshmen's programming basics

Some programming course teaches programming languages such as C language. It is difficult for students to understand computers from a computer system perspective.

Moreover, the teaching process emphasizes grammar teaching, lacks interaction with students and has little integration with students' majors. Students can't see the value of knowledge. In the long run, students will not be interested in learning. Even some teachers think that their responsibility lies in imparting knowledge and completing teaching tasks, and students' needs have nothing to do with themselves. This is bound to be difficult to arouse students' interest in learning and affect the effect of teaching.

Fifth, the course attaches great importance to knowledge learning and ability training, and pays less attention to value quality. In recent years, the country has paid attention to the ideological and political education of every curriculum. Therefore, in the process of carrying out the computer fundamentals course, teachers should organically integrate the ideological and political education with the teaching and learning content. The course must find suitable entry points, so that to help students to establish socialist core values while improving CT, and improve students' ideological and political level.

3 Related Word

3.1 Computational Thinking

There is no consensus definition or model of CT. In 2006, Wing proposed computational thinking is a basic skill for all humans, and computational thinking is a series of thinking activities covering the breadth of computer science, such as problem solving, system design, and understanding of human behavior using the basic concepts of computer science [5]. Wing's opinions provided a fresh perspective on the relationship between humans and computers, and gave rise to a wave of research on CT [6]. Bitesize defined CT as "Computers can be used to help us solve problems. However, before a problem can be tackled, the problem itself and the ways in which it could be solved need to be understood. Computational thinking allows us to do this…(it) allows us to take a complex problem, understand what the problem is and develop possible solutions. We can then present these solutions in a way that a computer, a human, or both, can understand." [7]. There are four key steps (techniques) to CT: decomposition, patter recognition, abstraction and algorithms. It is mentioned in the Chinese Senior High School Information Technology Curriculum Standard (2017 Edition) that students with computational thinking can use computer-processable methods to define problems, abstract features, establish structural models, and organize data reasonably in information activities [8].

With the development of big data and AI, many scholars have given new understandings and definitions of CT. These new understandings and definitions reflect the form and connotations of CT from different perspectives. Denning concluded that the thought processes of CT should include those of skilled practitioners of the field where the computation will be used [9]. He put forward thinking is the ability to design computations which is a skill set, not a body of mental knowledge about programming and computational designers in their fields of science will spend much of their time inventing, programming, and validating computational models [9]. Chen et al. regard the concept of CT 2.0 and believed that CT is the thinking mode adopted by scientists in all fields when applying computing and computing models, rather then the unique thinking mode of computer scientists, which change continuously with the development of computing models [10].

3.2 OBE

Outcome-based education (OBE) is an educational approach adopted worldwide today to ensure education quality, in which the learning outcomes about the course are decided at first. It was propounded by William G. Spady in the 90s. Spady described that OBE "means clearly focusing and organising everything in an educational system around what is essential for all students to be able to do successfully at the end of their learning experiences. This means starting with a clear picture of what is important for students to be able to do, then organising the curriculum, instruction, and assessment to make sure this learning ultimately happens" [11].

OBE adopts reverse thinking, first determine the learning outcomes of the course, and then according to the outcomes deduce the course design, teaching strategy and evaluation mechanism. The entire process of teaching and learning from the beginning to the end of the course revolves around the final learning outcomes. Learning outcomes represent a structure of competencies that are primarily achieved through the phasing of curriculum instruction. The course learning process emphasizes student-centered, students' own knowledge and ability construction, and emphasizes the progress of personal learning. Davis and Winch described some of the main advantages of OBE are the explicitness in its relevance, inherent clarity, accountability, self-directedness, flexibility, an integrated framework of teaching and learning [12].

3.3 Case Method

Case Method first originated from Harvard Law School in the United States and was introduced to China in the 1980s. Case method takes typical or demonstrative cases in the real situation around the certain teaching purpose and teaching content for students to think, analyze and practice. Students study those cases through independent research or mutual discussion under the guidance of teachers. Through the analysis and discussion of typical problems, students understand the correct knowledge points and learn the correct operation methods. Case method helps students integrate into the real situation, stimulate their interest in learning, and actively construct knowledge to improve their analysis and comprehensive ability and certain professional practical skills to solve real problems.

4 Curriculum Construction

4.1 Computational Thinking Hierarchical Competency Improvement Model

In order to solve the above-mentioned problems in the course teaching process of computer fundamentals course in Hunan university, a new teaching reform is going on from 2020 to meet the needs of the AI times. A new teaching strategy based on OBE and blended learning to cultivate computational thinking skills is adopted, and is combined majors to meet the goal of cultivating compound and innovative talents. Facing the development needs of AI era, CT has new form. Cultivating CT is not only to train programming skills, but also to cultivate thinking mode which is a way for people to solve

Table 1. CT hierarchical competency improvement model.

Capability level	Cognition	Method	Team comprehensive
Connotation	computing understanding and knowledge	computing method	knowledge transfer, comprehensive evaluation, innovation
Teaching objectives	cognition and interest	skills and knowledge	thinking and innovation
Teaching content	computing, CT and AI: overview	python, system, network, data, algorithm, AI computational model	team comprehensive training based on disciplines
Teaching method	connotative blended	case blended	team cooperation exploration
Evaluation mechanism	conceptual judgment	problem oriented programming	training report

problem integrated with their disciplines. According to the new features of the cultivation of CT ability, the course contents are reconstructed and the hierarchical model of cultivating CT competency is established, as shown in Table 1.

The improvement of CT ability is divided into three levels. The first level is the cognitive level. To develop CT, students must understand the related concept of computing, the history of computing and computer, CT, and AI development, computing system, computing execution and future computing. This part of content need 4 h, mainly to let students have a preliminary understanding of CT and arouse interest in learning. Students can enter the second level after mastering the basic knowledge related to CT.

The second level is computational method skills training, which focusing on developing students' problem-solving skills. The teaching contents mainly include Python programming basics and different thinking mode of CT including computing system thinking, algorithms thinking, internet thinking, data thinking, AI and intelligent computing. Python is used as a tool to solve problems, train CT, and embody the core concepts of computing, abstraction, automation and so on. Python language is not a simple substitute for other programming languages, but an inevitable choice with the development of computer technology [13]. Python has become the first choice for non-computer majors to learn programming and cultivate computational thinking [14]. In this level, case method is adopted through the complete process. For each case, according to the order of problem decomposition, pattern recognition, abstraction, algorithms and programming realization to train thinking ability and practical ability. In the problem-solving procedure, related knowledge is integrated into. This level needs the most teaching time, and adopted the method of learning by doing. Focusing on abilities and ignoring grammar.

Students are divided into four major categories: liberal arts, business, science and engineering, as shown in Fig. 2. Different cases related to the different discipline categories are designed based on the same teaching contents. From the second level, students learn different cases according to their discipline category.

The third level is the team synthesis training level. Team cooperation and comprehensive training combined with disciplines are adopted. Such as, for liberal arts students, there are job demand analysis and visualization of recruitment website, analysis of film box office ranking, and analysis and management of large ancient poetry data set. For business students, there are milk tea shop service system and stock analysis. For science and engineering students, there are garbage detection and house price prediction. In this level, it is emphasized to carry out computing design and innovation in the way of thinking of computing in various majors, so as to cultivate teamwork ability.

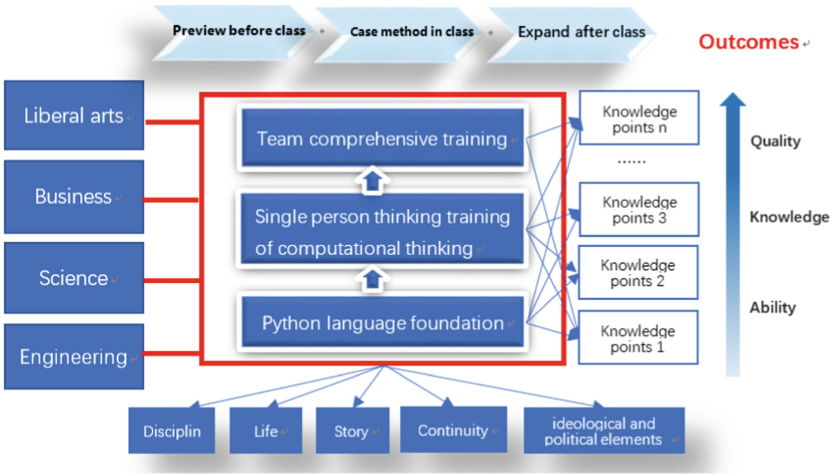

Fig. 2. Implementation of case method and ability training teaching reform

4.2 Case Design

The key point of this teaching reform is to design good cases and used in teaching. The following characteristics are considered when cases are designed:

First, the cases cover all the learning outcomes of the computer fundamentals course. According to the CT hierarchical competency improvement model, including Python languages foundation training cases, CT different thinking mode training cases, and team comprehensive training cases.

CT different thinking mode training cases include computing system thinking, algorithm thinking, network thinking, data thinking and AI model. Some cases are shown in Table 2 and Table 3. The hierarchical cases not only pay attention to the cultivation of students' individual ability, but also to the cultivation of students' comprehensive team ability, and cultivate students' team consciousness and cooperation spirit.

Second, cases are constructed separately according to disciplines and professions, and divided into four categories: liberal arts, business, science, and engineering. Science cases are mainly theoretical science cases, such as calculating the shooting curves of basketball from different angles. Engineering cases are mostly engineering cases, such as

Table 2. Python language foundation cases

Situation	Python language foundation cases
Classroom	Length conversion Wheat on the chess board Extracting information from student number Caesar Code Encryption Hurricane classification determination Calculation of water charges Players score statistics Random password generation Shooting curves of basketball calculating ID card number verification
Experiment	Currency conversion The power to make progress every day Extract information from the ID number Caesar cipher decryption Grade judgment Electricity calculation Examination Result Statistics Simulation student number generation Bar code check
Extension	Two-way currency exchange Caesar cipher with variable key The root solution of any quadratic equation of one variable Grade examination results statistics Narcissus number and four leaf rose number Article word statistics Analog ID number generation Binary search Output ancient poems in different formats

handwritten numeral recognition. Liberal arts cases are mainly text analysis and natural language processing cases, such as the appearance statistics of characters in "The Story of the Stone". Business cases are mainly financial management cases, such as listed companies stock analysis.

Third, the course case library has been established, including classroom training cases, course experiment cases and extracurricular expansion cases, some as shown in Table 2 and Table 3. Taking classroom training cases as an example, under the guidance of teachers, students are driven to solve problems with CT. The teaching is carried out in the way of imitation-migration-expansion to realize consolidating exercises, and combining "studying" and "practicing" effectively. Students acquire knowledge through the studying process, and internalize knowledge and improve their ability through the process of practicing. The whole teaching process is well planned and designed.

Fourth, few cases are simple mathematical problem-solving cases, most cases come from real situations and have a certain complexity. Some cases come from real life, such

Table 3. Computing method cases

Situation	Computing method cases
Classroom	"The business of Venice" word frequency statistics Statistics of appearance times of characters in "The story of the Stone" and drawing of the relationship between characters Word cloud of the government reports Sentiment analysis of current affairs review Batch generation of lawyer letters Group map crawling Face detection Handwritten numeral recognition Information crawling of Yuelu Academy Forum Listed companies stock analysis
Experiment	"Jane Eyre" word frequency statistics Statistics on the number of appearances of characters in "the Romance of the Three Kingdoms" Song lyrics word cloud Sentiment analysis of film reviews Batch generation contracts Campus images crawling Admission score crawling, extraction, analysis and visualize
Extension	Word frequency statistics and word cloud generation in Hemingway's novels Batch generation of PPT files Final score data analysis and visualize Dynamic graph display

as the calculation of water charges, computer files classification, photo face detection. Some cases have the characteristics of storytelling, such as the tower of Hanoi problem. Some cases combine professional content, such as mass production of lawyer's letters and drawing of the relationship between characters in "The Story of the Stone". Continuity of the cases is also considered.

Fifth, ideological and political elements in the course are fully excavated, and organically integrate into various cases, including classroom training cases, experimental cases and after-class extension cases, so as to achieve the effect of moisturizing and educating people silently. For example, students have a deep understanding of the spirit of science by learning the case of scientists' pictures recognition, understand the excellent ancient Chinese culture through the cases of analysis of Chinese ancient poetry, enhance legal awareness through web crawler cases, improve security awareness through the case of credit card number authenticity identification. Through a large number of cases, students' computation thinking abilities to solve practical problems are cultivated, students' good personality quality and value orientation are established at the same times.

4.3 Teaching Method

Combining the hierarchical competency improvement model of CT and the OBE driven, each level adopts different teaching method. However, the online and offline blended teaching mode are all adopted. Many resources of MOOCs and micro-lectures are designed and displayed in Internet teaching and learning platform (http://www.educoder.net). There are not only MOOCS resources of CT and artificial intelligence, but also micro-lecture resources of professional cases analysis.

Students are required to watch MOOCs or learn materials before class. Multi teaching methods are adopted in class time. Students watch micro-lecture and don exercises after class. Educoder network platform are used to carry out experiments and to assist various teaching activities. Teaching mode has shifted from teacher-centered to student-centered. In the cognitive level, connotative blended is adopted, and teachers organize students' discussions. In the computing method level, cases blended is adopted, and students complete their task independently, but the team collaborative learning let students get help from each other. In the team comprehensive level, students' group can obtain resources from internet, and explore by themselves. Each person completes the relevant sub-modules of the project, and conducts results presentation and defense. Students can learn and practice independently before class. In the classroom teaching, grammar details and algorithms are not involved. Grammar can be found on the Internet, from the exchange of students to solve. After class, students can further improve their ability and expand their horizons through cases with certain depth or difficulty.

4.4 Teaching Assessment

Each level of the hierarchical competency improvement model of CT adopts different assessment. The first level pays more attention to the mastery of knowledge. The classroom quiz and classroom discussion are used as the basis for judgement. The classroom quiz is mainly simple choice questions in concept judgment. Classroom discussion focuses on participation and contribution. The second level is judged by programming ability. The main basis for judgement is the completion of the class cases and experiment cases. In the third level, students need to submit a report, display their outcomes, and answer questions. In this level, score of other students and teachers are integrated together.

5 Analysis of the Teaching Effect

The OBE based and blended ability training teaching reform has been carried out from the fall semester 2020 in computer fundamentals course in Hunan University.

By adopting the way of blended teaching mode and ability training, the course objectives are gradually achieved from the aspects of different cases, teaching organization and implementation, and the differentiated teaching is realized through fine-tuning of class hours and content as well as the professional characteristics of experimental content. Study groups about 3–5 people are set up during the course. Open teamwork encourages students to find solutions together, and promotes students' team spirit. It realizes the transformation of learning as the center.

Multi-dimensional evaluation methods are used to evaluate students. For example, student-student mutual evaluation, class quiz, big homework, mid-term exam and final exam, as shown in Fig. 3. Usual performance 1 is consists of classroom performance and big homework. Usual performance 2 is consists of homework of computational thinking after class and the average score of each experiment.

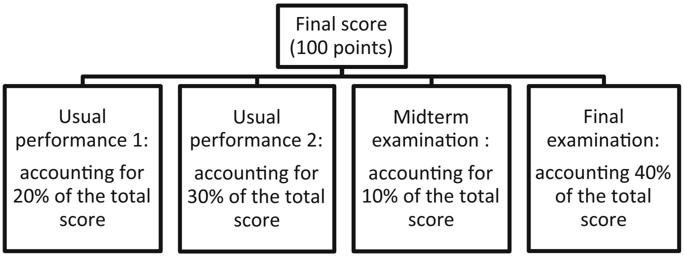

Fig. 3. Evaluation method of computer fundamentals course

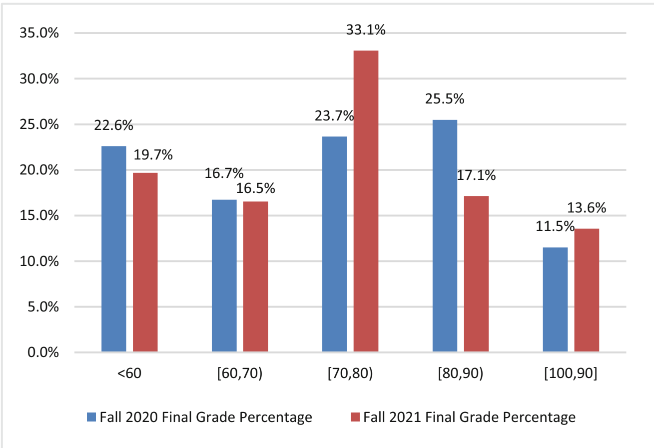

Fig. 4. 2020–2021 fall semester final grade percentage comparison

Anonymous questionnaire surveys have been distributed many times to collect students' learning effects, and the teaching reform has been recognized by most students. From an anonymous questionnaire survey conducted with students at the end of the term, most students are interested in most of the contents of this course. The final grades percentage of fall semester 2020 and 2021 are compared, as shown in the Fig. 4. With the accumulation of teaching experience and the continuous improvement of teaching, the final grades percentage of fall semester 2021 are significantly better than those of 2020 under the same test question type and test difficulty.

6 Conclusion

Through the new teaching reform of the computer foundation course, two main lines of knowledge and practice are iteratively integrated, and knowledge points are implanted in case learning. By promoting teaching with case practice, it can gradually improve the ability and thinking mode of using CT to solve problems through incremental learning. Although the teaching reform of computer fundamentals course has archived gratifying result, there are still insufficient. For example, the difficulty of case-driven teaching lies in the acquisition of professional needs and abstraction of problems. More and more cases should be found and designed to meet the need of each major. There is a big gap in students' computer basic knowledge, we need to design more reasonable layered cases. Other course resources also should be provided for different basic level of students. On the other hand, we should improve the question bank of the quizzes system, enrich the question bank.

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Research on College Students' Network Security Education Under the Background of Ideological and Political Education

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Abstract. With the rapid development of Internet plus and big data, college students are facing many threats and risks of network security. Strengthening the education of network security for college students has become an important problem that needs to be solved urgently in higher education. By analyzing the causes of the problems existing in the current network security education, this paper puts forward some measures, such as building a solid network security barrier, building a perfect network security knowledge system and diversified forms of education, to strengthen the network security awareness and prevention skills of college students.

Keywords: Ideological and political education · College education · Network security education

1 Introduction

At the first meeting of the central network security and Informatization Leading Group, General Secretary Xi stressed that "without network security, there will be no national security". Nowadays, the problem of network security also puzzles the personal and property safety of college students. There are more and more cases of network fraud, which has a certain negative impact on the physical and mental health of college students. Therefore, it is imperative to carry out network security education for college students in the new era [1].

2 The Necessity of Integrating Ideological and Political Education into Network Security Education

With the rapid development of the Internet, the majority of college teachers and students have become the largest group of network applications. The network not only provides great convenience for teachers and students in teaching, life and work, but also faces

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severe challenges. In view of the mixed information on the network will have a certain impact and impact on the thoughts and life values of college students, some college students have suffered from online scams, the password of online transaction account has been leaked, online games have become the main entertainment mode of the youth generation, and bad information published on the network. These problems will affect the physical and mental health of college students and the correct development of their outlook on life. In view of such network phenomena, it is necessary to bring network security education into the talent training mode, strengthen college students' network security awareness, improve their self discrimination ability and awareness and self-protection awareness, and create a good campus network environment. At the same time, the combination of education and mental education and the continuous improvement of Ideological and political education play a great role in promoting campus network security education [2].

With the popularization of network application, college students are affected by some bad information on the network, so it is difficult to establish a correct outlook on life and values, and it is difficult to really focus on professional learning. Some are even addicted to online games and online novels, and some are affected by the phenomenon of Online fraud on campus. In view of the above problems, the cultivation of contemporary college students should put morality and people first, To solve the problem fundamentally, the ideological and political education of the course should run through the whole teaching process. Therefore, it is necessary to cultivate campus college students' network security awareness and network security skills. Starting from the ideological and political training of students, combined with the curriculum characteristics of various majors and the current network security problems, it is urgent to improve the teaching methods and teaching level of contemporary college students' Network Security Education [3]. Therefore, building a perfect campus network security system, improving students' Ideological and political understanding and ensuring the campus network security environment of contemporary college students is an important problem that needs to be solved urgently in the field of education in the information age.

3 Problems in Current Network Security Education

3.1 Insufficient Efforts to Strengthen Network Security Education in Colleges and Universities

In his speech at the national network security and information work conference, General Secretary Xi mentioned that "there is no national security without network security". Since then, the state and all departments have attached great importance to it. However, colleges and universities have little awareness of network security education, and there are still incidents such as network fraud and information leakage, which have affected the physical and mental health of students. The main reason is that colleges and universities regard network security management as the responsibility of a functional part. Managing the campus network environment is to do a good job of network security, ignore the constraints on students' network behavior, and lack the guidance of security education. School security education mainly focuses on Ideological and political theory courses or computer courses. The contents and methods of network security education mastered by contemporary college students are difficult to cope with a series of new network security problems with the rapid development of the network [4].

3.2 The Campus Network Security Environment Needs to Be Strengthened

Nowadays, the Internet has become a part of people's life, and its impact on College Students' campus study and life can not be underestimated. The Internet is also a large information platform for college students to obtain knowledge, online courses, make friends, entertainment, job hunting and so on. While enjoying the convenience, college students also bring some negative effects. The good and bad network information affects college students' thinking style, outlook on life and values, and their views on the country, society, work and life. The Internet also makes some college students indulge in online games and online novels, which has a serious impact on their studies and life. Meanwhile, the era of "Internet plus" also makes personal privacy information face various challenges. Network "human flesh search", hacker attack, information disclosure, mobile phone eavesdropping, virus intrusion, monitoring personal sensitive information and other behaviors are hard to prevent [5]. Therefore, the construction of network security environment directly affects the degree of campus network security risk. The network security management departments of each school shoulder the important task of ensuring the network security environment and do a good job in the construction and maintenance of network facilities, involving network communication equipment, network terminal equipment, network software, etc.

3.3 Contemporary College Students Have Superior Growth Conditions and Weak Awareness of Network Security

With the rapid development of society and the stability and unity of the country, people now live a happy life. Most of the family living conditions of contemporary college students are superior, and every child is the hope of the family. Parents try their best to meet the needs of their children, and no matter how hard they work, they will provide better learning protection. Such a growth environment has led to some students' weak safety awareness and weak self-defense and self-protection ability, At the same time, due to the mixed network information, college students' recognition ability of network information is not enough. Therefore, in the new era when online shopping and online games are popular, college students' personal information is leaked due to the security problems of the network environment when registering their account or online recharge.

3.4 The Form of Network Security Education in Colleges and Universities is Single

With the rapid development of network technology, colleges and universities have quickly entered the period of information processing of daily affairs, transforming from the traditional education mode to information and digitization. Although the traditional education mode can not meet the training needs of contemporary college students, due to various changes in the situation, they have also carried out teaching modes such as online live classroom, flipped classroom and online and offline mixed teaching. Now, they vigorously promote ideological and political education, Strengthen the integration of Ideological and political elements into classroom teaching of various disciplines and integrate with the development of the times. However, in the course teaching process, the teachers still adopt the traditional teaching mode, inserting a network security example or playing a network security video in the classroom to let the students understand the network security problems. This mode is like embedding an advertisement in the classroom, which can not attract the special attention of the students, and the students do not really participate in the network security education, Arm yourself with network security knowledge and skills. If a single teaching method is still used for ideological and political education, the effect is still very little [6]. Therefore, strengthening campus network security education in multiple dimensions can create a good campus network environment.

3.5 Contemporary College Students Have Poor Ability of Network Self-control

For freshmen, they have just experienced the intense learning pressure of three years in senior high school. After entering the University, compared with the learning and living environment of senior high school, the university has more autonomy and flexible free time. Some students are affected by external factors and confused by network information to find happiness and release pressure in the network. There are also some students who have just entered a new environment. How to get along with students with different personalities and life backgrounds requires a certain adaptation period. These students will choose to escape, rely on the network and invest themselves in a virtual world. In this way, freshmen are most likely to form internet addiction, so they are misled by some improper remarks and bad information on the Internet and are easy to distort their values. Because college students have weak discrimination ability, they are also easy to be targeted by some criminals. Therefore, freshmen are the group with the highest incidence of network security incidents in Colleges and universities, Campus network security education has become a primary concern in the cultivation of college students.

4 Implementation Measures of Strengthening College Students' Network Security Education

By analyzing the current situation of College Students' network security education in the new era, this paper analyzes the reasons for the current campus network security events. In order to better solve the problems and provide network security for teachers and students, we will strengthen the decision-making of College Students' network security education from the aspects of Internet Environment, network security education knowledge system, education form and so on.

4.1 Change Ideas and Improve Safety Awareness

Ideas are the guide of action and ideas are the guide of practice. Only by changing ideas can we effectively guide the development of various work. Only by fully recognizing the scientificity and systematicness of the content of College Students' network information education can we improve the security awareness and organically combine the increasingly urgent network security education with the quality education of cultivating high-quality qualified talents. Therefore, the college can set up a quality education development center to be responsible for the quality education development of college students, especially the network security education and psychological security education of college students.

4.2 Build a Solid Network Security Barrier

With the development of the network, the majority of teachers and students not only rely on the network, but also choose many ways to surf the Internet. They roam online all the time. Therefore, the school network center should establish the first security line for teachers and students. Strengthen the construction of campus network security infrastructure, set rules for campus network firewall, shield some illegal access, filter the spread of some bad information, ensure the security of information resources viewed by students, protect students' personal information from infringement, supervise campus network security vulnerabilities, and do a good job in identity authentication of campus network access. Arm the campus network with technology and create a green network environment for students.

4.3 Institutionalization of Safety Education

Network security education should constantly adapt to the changes of the situation and keep up with the pace of the development of the times. We must adhere to reform and innovation and establish the concept of scientific development. Realize diversified network security education and management on the basis of not limiting content, time and form. The college can establish a network security teaching platform to enrich students' knowledge. At the same time, technical means can be used to filter the bad information on the network to the greatest extent by displaying rich and colorful multimedia resources and the "green network" action of the campus network.

4.4 Establish and Improve the Long-Term Mechanism for the Operation of College Students' Network Information Security Education

The college can build a quality education and training center led by the Department of study and work, often carry out quality development training in various forms, and be specifically responsible for the safety education of college students. At the same time, it can conduct network security practice exercises, use some of the latest security means to carry out practical exercises, improve students' safety awareness and implement the contents of safety education, Counselors, teachers and head teachers can organize the explanation of network security cases to students at the class theme class meeting, and bring the safety education of college students into the whole teaching plan of the school. Grasp students' psychology at any time, form a planning and implementation system, and truly implement network security education (Fig. 1).

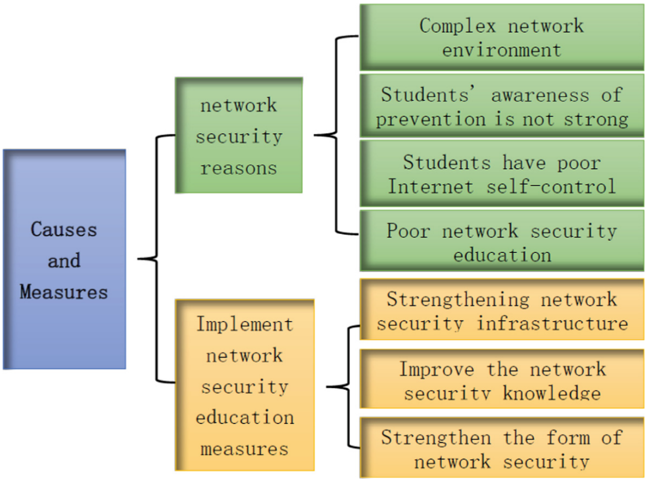

Fig. 1. Implementation measures of network security education

4.5 Build a Perfect Network Security Knowledge System

In today's world, network technology goes deep into people's daily life. Maintaining network security is the due social responsibility of every citizen. We need everyone's joint participation and improve the people's awareness of network security. Therefore, network security education is included in college classroom education and teaching, the relevant contents of network security are reflected in the chapters of information courses, and the relevant contents are added to the knowledge system of students' literacy, so that students can imperceptibly receive network security education. In the new era, college students' access to network security knowledge is not only in the teaching content of university computer courses, but also in the whole education process. In the talent training program, network security education should be integrated into the knowledge system of general courses and professional courses. Improve students' network security awareness and network processing ability ideologically. Therefore, we should build a pattern of full staff, whole process and whole course education, integrate network security education into curriculum ideological and political education, and peer professional courses with ideological and political courses. The classic cases of network security will be good curriculum materials in curriculum ideological and political education. Through the playback of network security examples, students can understand the connotation of curriculum ideological and political education and improve their awareness of network security.

4.6 Building Diversified Forms of Education

Course teaching is the main form of education. While giving full play to the main role of course teaching, college students' network security education can also give full play to the role of the second classroom and adopt diversified forms of education to carry out network security education. From the network security knowledge education, we can promote the network security education knowledge through carrying out lectures on network security education, network safety education theme class meeting, network security education open class, network security knowledge official account, online topics, network security Week activities, campus announcement columns, so that every student can have a chance to browse and learn. In terms of publicity form, we can attract the interest of all teachers and students through the graphic analysis of security cases such as publicity videos, "personal information protection", "online dating fraud", "online rumor management"; Or carry out network security education through special websites, microblog, wechat, electronic newspaper reading column, mobile newspaper, QQ, wechat, campus radio and other ways; From the perspective of network technology, through carrying out network security community activities, campus network security attack and defense drills, network security knowledge competitions, etc.; Improve the network security awareness of all teachers and students through various forms, strengthen their own defense ability, constantly standardize their own network behavior, and create a healthy and civilized campus network environment.

5 Summary

Network security has become a hot issue in today's society. While the rapid development of network has brought great convenience to our daily life, there are also many traps and unsafe factors. Due to the increasing demand of college students for the network in the new era, college students' network security education has become an indispensable part of the field of education. Due to the impact of the network environment, students' own network security awareness is not strong, colleges and universities lack network security education for students, single form of education and other problems, it is imperative to popularize network security knowledge and network security operation skills for teachers and students on campus, Improve the network security awareness of contemporary college students in various forms, create a green network environment, and further enhance the consciousness and initiative of teachers and students to maintain national network security.

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Practice on Integrated Curriculum System of Prefabricated Building Based on X-Certificate

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Abstract. Based on the analysis of occupation post ability and the integration of the X-certificate standard, the specialty group of architectural decoration engineering technology respectively constructs specialty group curriculum system of three modules and two fusion which is suitable for 5 major fields of architectural decoration engineering technology, construction technology, architectural design, engineering cost and property management, and persists in the organic combination of occupation orientation and learning objectives, and takes the training of compound innovative technology skilled talents as the guidance. Optimize the modular curriculum system of "specialty basic platform + specialty module (X-certificate) + personality development", realize the ability centered talent training process according to the formation order and needs of ability, and form a curriculum system of "project through ability training and action to promote ability formation".

Keywords: Specialty Group · X-certificate · Curriculum System · Prefabricated Buildings

1 Introduction

1.1 A Subsection

According to the requirements of enterprises, the courses are set, the skills are set according to the post standards, the quality is tested according to the social evaluation, the development of the specialty group guided by the social needs is highlighted, the market, enterprises, posts and social needs are put in the first place in the development of the specialty group, and the social attributes, professional characteristics and characteristics of each specialty in the specialty group are strengthened. Strengthening the connotation construction of specialty group, making the specialty group have the forward-looking, advanced and driving ability, based on the analysis of the occupation post ability, and integrating into the X-certificate standard requirement, respectively constructs the three modules and two fusion specialty group curriculum system suitable for 5 specialties of building decoration engineering technology, construction engineering technology, architectural design, engineering cost and property management. Adhere to the organic

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combination of career guidance and learning objectives, take the cultivation of compound innovative technical talents as the guidance, optimize the modular curriculum system of “specialty basic platform + specialty module (X-certificate) + personality development”.

At the same time, the dynamic adjustment of curriculum system and curriculum standard updating mechanism should be established. By introducing the advanced concept of international vocational education and the national professional teaching standards, integrating the ideological and political elements of “cultivating morality, cultivating people and cultivating faith” and the spirit elements of “meticulousness, delicacy and delicacy” craftsmen, the “X” vocational skill level certificate requirements and new technologies, new crafts and new norms into the teaching content, a set of school-based curriculum standards and practical training standards for specialty groups are developed, Realize the integration of skill training and professional quality training.

2 Talent Training

2.1 Talent Training Mode of Specialty Group

According to the specialty characteristics of lean construction and taking “building integration - digital design - prefabricated decoration- intelligence maintenance” as the main line, the specialty group of architectural decoration engineering technology constructs the innovation of “integration of courses and certificates and ability standard” of prefabricated building integration based on information technology.

2.2 Occupation Post

The specialty group of architectural decoration engineering technology connects with the construction industry chain. The professional group of architectural engineering technology provides technical solutions for the green transformation of the construction industry, undertakes the core technology of lean construction, and implements industrial production and assembly construction; Architectural design is oriented to the integration, standardization and component integration of architecture and interior decoration; The major of architectural decoration engineering technology jointly implements talent training in the direction of industrialized production, assembly construction and information management of indoor and outdoor decoration. The construction cost chain provides effective guarantee for the efficient and professional construction cost control. The property management specialty provides all-round intelligent management and control for lean construction projects, realizes the integration and efficient collaborative management of various business links, realizes the intelligent transformation of the construction industry, and provides intelligent operation and maintenance technical support. The 14 typical posts in the group are mainly concentrated in production links such as drawing, design, construction, supervision, budget and technical management.

2.3 Core Ability

Under the concept of result oriented education, combined with industry development, job needs, advanced experience of brother colleges and students' sustainable development requirements, it is determined that the core competencies of talent training are: communication and cooperation (cooperation), learning and innovation (learning), responsibility (responsibility), problem raising and solving (thinking), professional skills (professionalism) and professional quality (Development), Follow the curriculum development mechanism of "post leading, achievement center, scientific setting and continuous improvement", deepen the reform of talent training scheme, build specific measurable professional ability indicators according to core competence, reconstruct the curriculum structure, and form a general module of professional group, general module of post group, post core competence module and career development module, which vertically echo the core competence and competence indicators, Reverse design the curriculum system from top to bottom. Horizontally integrate specialty, teachers and training resources to realize resource co construction and sharing.

2.4 Curriculum Standard Design

In terms of curriculum standard design, it takes the post ability as the center and the working process as the basis to refine typical work tasks and develop learning scenarios targeted. Through enterprise research and graduate return visit, modular teaching and modular assessment are realized according to the job demand and work process, based on the analysis of typical work and the professional demand of the job. The design of the curriculum standard considers the high integration of "work" and "learning", pays attention to the combination of theory and practice, and connects with the post needs to realize the cultivation of professional ability. At the same time, strengthen the design of comprehensive quality courses and cultivate students' innovative spirit and quality (Fig. 1).

The curriculum standard content is designed according to the course of students' learning activities and the actual working process of the post. Transform the contents to be mastered in the theoretical knowledge points into the task points to be completed by the project, import them with actual cases, and cultivate students' six core abilities through project training. Through the multi-directional cultivation in the form of task leading, project driving and group cooperation, students' learning interest, enthusiasm and initiative are better mobilized, and students' thinking ability, innovation ability and sustainable development ability are strengthened.

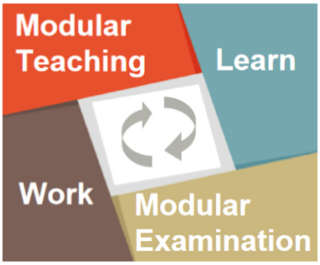

Fig. 1. Schematic diagram of core principles of curriculum standard design for speciality groups

3 Implementation Measures

3.1 Practice the Reform of "Three Educations" and Promote Classroom Revolution

With the cultivation of the characteristics of professional groups as the main line, carry out education and teaching reform with the cultivation of developmental, innovative and compound technical and skilled talents as the core. Reform teaching methods and means, strengthen the concept of "student-centered", widely use heuristic, inquiry, discussion, participatory and studio teaching to stimulate students' motivation for active learning, pay attention to students' vocational cultivation education, and enhance students' learning ability and sustainable development ability. Apply modern information technology to transform traditional teaching, explore flipped classroom and mixed classroom teaching, and promote the formation of mobile and personalized learning methods. Strengthen the learning process management and assessment evaluation with the goal of educating people, and implement the post replacement and job rotation of students during the post internship according to the training objectives. Deepen education and teaching reform, cultivate major theoretical research achievements, publish high-level teaching research papers, actively participate in the application of provincial and national teaching achievement awards, strive to win awards, and give full play to its leading and exemplary role (Fig. 2).

Fig. 2. Schematic diagram of the relationship between reform of three educations

Reform of Textbook. The teaching content introduces new technologies, new processes and new norms of the industry. The content arrangement is consistent with the teaching methods such as task-based teaching, modular teaching and case teaching. The prefabricated building is embedded in a series of teaching materials from architectural drawing, architectural structure, architectural and decoration construction technology, architectural engineering measurement and pricing to comprehensive practical training of architectural engineering, and a batch of standardized teaching materials reflecting the prefabricated building are built. Selecting and building "Interne + " three-dimensional teaching materials. In the specialized course and practical teaching, we should choose "Internet + " teaching materials that match the information teaching.

Reform of Teacher. Adhere to the principle of "school enterprise cooperation, full-time and part-time combination, key training and strengthening introduction", pay close attention to the construction of professional leaders and backbone teachers, strengthen the construction of "double qualified" teaching team with "double high" (highly educated and highly skilled) as the standard, and strive to build a full-time and part-time teacher team composed of professional leaders, backbone teachers, "double qualified" teachers, industry experts and technical backbone hired from industries and enterprises. Relax the introduction conditions for the scarce craftsmen of enterprises. Standardize the enterprise practice training system for teachers, include this into the professional title evaluation conditions, encourage teachers to participate in school infrastructure projects, and improve teachers' professional skills and the proportion of "Double Teachers". Use online and offline to carry out training on the improvement of teachers' ability and information-based teaching ability for existing teachers, so as to improve teachers' teaching ability and comprehensive quality. Set up a structured teaching team, such as drawing group, structure group, budget group, etc., and divide the work of writing for modular teaching. Promote the 1 + X certificate system, train key teachers to become certificate "trainers", so that teachers can not only teach in schools, but also carry out vocational qualification training, and enhance their social service ability.

Reform of Pedagogics. The school classroom carries out the reform of teaching methods such as situational teaching, modular teaching and practical project guidance, and combines teaching with enterprise post tasks to achieve the integration of industry and education. Using innovation of online and offline hybrid teaching mode. Make use of the existing digital teaching resources such as high-quality online open engineering and online and offline hybrid courses to change the traditional teaching classroom and develop the second classroom to meet the students' needs of learning, communication, answering questions and solving doubts anytime and anywhere (Fig. 3). Take the school infrastructure construction site as a place for practical learning. From materials, technology, construction technology to project management, students can go to the construction site to study. At the same time, they can make videos of the construction process on the construction site and incorporate them into teaching resources to facilitate students to study at any time. Enterprises with graduates as entrepreneurs are incubated in the professional group. Companys are located in the school and funded by the school. Students carry out practical exercise in the enterprise, and take the senior and junior students to achieve the purpose of cultivating students.

Fig. 3. Schematic diagram of hybrid teaching mode on and off the line

3.2 Construction of Teaching Resources

Practical Teaching System. In the course construction and reform, we should enrich and improve the professional teaching steering committee dominated by enterprise technology and management personnel, adhere to the basic knowledge, resolutely get rid of the shackles of the "discipline type" system, take the principle of necessity, sufficiency and consideration of follow-up development as the principle, follow the goal of serving "reality, practicality and practice", and adhere to the principles of "comprehensive implementation of professional basic courses" and "mature technology and management norms for professional course teaching", Conduct in-depth analysis and demonstration on the current curriculum system, and form a perfect curriculum system reflecting the combination of work and study and practical teaching. In particular, we should strengthen the construction of practical curriculum system and build an independent practical teaching system, especially the practical teaching system with vocational ability training as the core. Take the backbone teachers as the curriculum leader, absorb enterprise technical experts, form a diversified curriculum team of teachers, organically combine the post standards and vocational skill appraisal standards, carry out the construction of high-quality core courses to cultivate students' key abilities in vocational posts, and form an autonomous learning network course.

Digital Resource Platform. Network-based curriculum teaching is a teaching process based on modern educational thought, modern information technology and multimedia and network. It has the advantages of interactivity, sharing, openness, cooperation, autonomy, freedom from time and space, many high-quality resources and convenient use. It is not only an innovative education model, It is also an important part of the education for all and lifelong education system. During the construction of this professional group, the construction level will be gradually improved based on the construction of three professional teaching resource libraries of architectural engineering technology, architectural decoration engineering technology and architectural design. At the same time, the teaching management mode will be changed according to the resource construction. We build a digital resource platform including a variety of resources, such as excellent online open courses, online and offline hybrid gold courses, offline project gold courses, textbook by school and enterprise co-edited and five high-quality platform courses, so as to realize co-construction and sharing in specialty group.

Construction of Training Base. We build a training base of virtual reality simulation with open and shared in the school based on the core skill training of all specialties in the specialty group and on the basis of existing training studios. We Optimize and integrate six public basic training platforms. We build training bases outside the school with well-known enterprises. According to the requirements of "from the site, higher than the site", highlight the construction of real or simulated environment, and transform the training center and training base. And strengthen the management of the training base, especially the establishment of the sharing mechanism inside and outside the school, and implement the enterprise management and market-oriented operation. The enterprise management is mainly to create an enterprise professional atmosphere. The training methods and processes are enterprise oriented. The market-oriented operation refers to the accounting of the training cost according to the market requirements, and strengthen the equipment management, tool management, material management and teaching management, Through scientific management, we will gradually form a series of training projects, supporting training materials, first-class instructors and perfect management norms. Ensure the construction of a high-level training base for higher vocational education with strong educational reform, high equipment level and high-quality resource sharing. Expand the engineering material testing center and engineering survey training center, upgrade and transform the building information model training room, build a new construction engineering drawing, drawing recognition and drawing review training base, build a new construction engineering virtual simulation center, a new BIM Engineering Center, a new fabricated engineering training center and a fabricated construction teaching platform, a new building MR intelligent laboratory, building planning and design studio, a new virtual simulation training center "Comprehensive practice base of project cost on campus", "model technology training room", "architectural decoration art and entrepreneurship incubation base", etc.

Technology Innovation Platform for Specialty Group. We implement education of Innovation, creativity and entrepreneurship, build skill master studio, and incubate students' innovation and entrepreneurship; Relying on the innovation platform of architectural decoration technology and skills, build six service centers, including prefabricated building research center, mobile information measurement center, BIM collaborative education center, architectural decoration design creative center, intelligent building space research center, engineering material testing center, etc., and landmark achievements such as scientific research and social service platform and intellectual property rights have been built (Fig. 4). Establish a working mechanism to actively carry out technical services to the society, carry out research aiming at the practical problems in China's infrastructure construction, and the research results have an important impact on engineering practice and play a positive role in promoting social progress; Establish and improve the incentive system for professional teachers to closely contact construction enterprises and serve the industry and society, participate in enterprise technical creativity and R & D, and improve technical service ability; Establish a construction vocational skills training center to provide vocational skills training services for construction enterprises and society, expand the retraining of social on-the-job personnel, vocational qualification certificate training and certification, and cultivate talents urgently needed for the construction development of Dawan district; Carry out horizontal projects and enterprise technology research projects at multiple levels, and the average annual amount of accounts received shall not be less than 1 million.

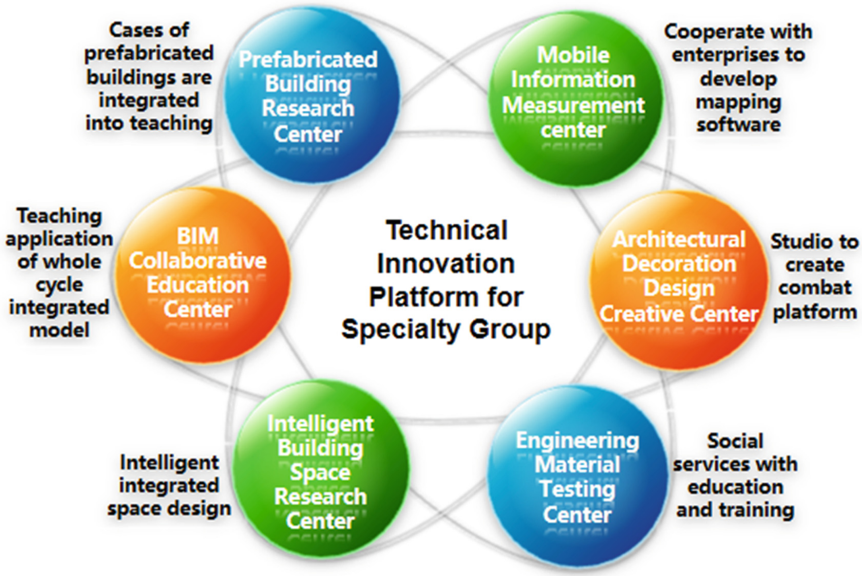

Fig. 4. Composition diagram of technical innovation platform for architectural decoration engineering

4 Construction Effectiveness

Adhere to the organic combination of career guidance and learning objectives, take the cultivation of compound innovative technical talents as the guidance, optimize the modular curriculum system of "specialty basic platform + specialty module (integrated into x certificate) + personality development", set up 3–5 general specialty basic courses in the general platform module, and jointly develop and promote the "X" vocational skill level certificate, Certificate module set 8–12 specialty core curriculum, personality development module set up 8–20 personality development courses, to ensure the effectiveness of the ability training in the process of education and teaching, and reasonably carry out the relevant ability training in the limited teaching time. The training process is based on the order and needs of ability formation to realize the ability centered talent training process, and form a curriculum system of "project through ability cultivation and action to promote ability formation" (Fig. 5).

Through the construction of specialty group, the college will be built into an international talent training base dedicated to China's Renaissance, promoting national industrial upgrading, conforming to the national industrial strategy and having a comprehensive industrial frame, and provide high-quality industrial talents within the whole industrial chain.

Specialty group of building decoration engineering technology has five directions, including space transformation, garden design, municipal engineering, smart home and Internet plus. At present, the professional group is developing in coordination with multiple majors, with high-quality teaching innovation team and excellent experimental and training base conditions, and the scientific research innovation system is gradually improved. The specialty group has distinctive school running characteristics, advanced education concept, and talents have an international vision. According to the general idea of the "2332" talent training mode reform of the University, the talent training mode of "integration of work and learning, project orientation, equal emphasis on morality and technology, and integration of entrepreneurship and innovation" has been explored and improved on the basis of many years of practice, which has laid a solid foundation for cultivating high-quality and high skilled double high talents with professional ability, innovation ability, sustainable development ability and international vision.

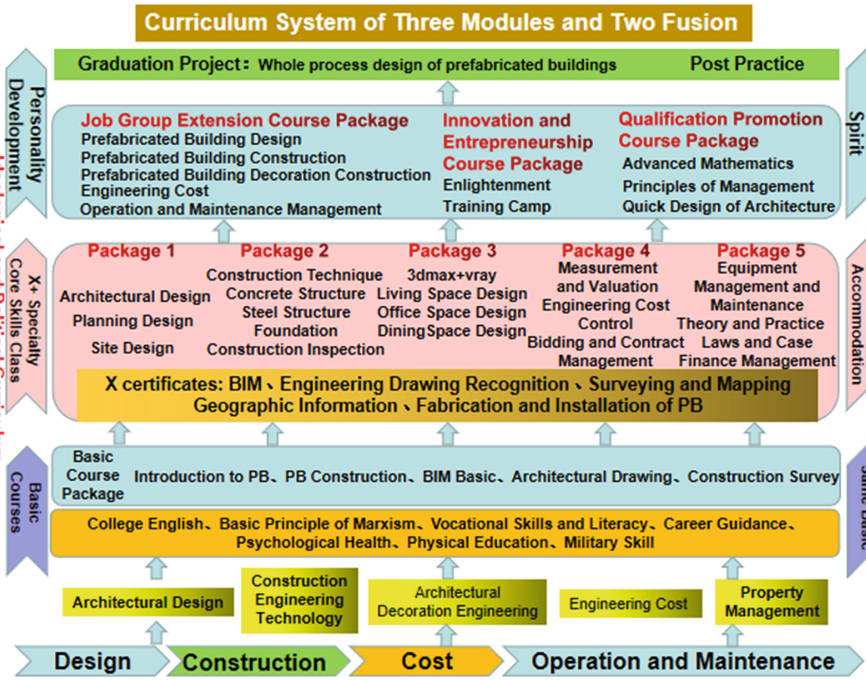

Fig. 5. Curriculum system of Specialty Group of architectural decoration engineering technology

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Research on University Computer Education from the Perspective of Aesthetics

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Abstract. University computer is the core course of science and engineering colleges. It is necessary to strengthen the penetration of aesthetic elements in computer education. In this paper, we analyze the current situation of aesthetic education in universities and propose several strategies of integrating aesthetic education elements into computer teaching from specific teaching links such as classroom, experiment and practice.

Keywords: Aesthetic Education · Computer Education · High-Level Language Programming

1 Introduction

Aesthetics is a discipline that studies the aesthetic relationship between people and reality. It focuses on cultivating people's correct aesthetic concepts, noble sentiments, the ability to feel, appreciate and create beauty. It is a cross-combination of aesthetics and pedagogy. As a result, it occupies an extremely important position in the process of cultivating people's all-round development.

1.1 The Current Situation of University Computer Aesthetic Education

In 1993, as the "Outline of China's Educational Reform and Development" proposed: "Aesthetic education plays an important role in cultivating students' healthy aesthetic concepts, aesthetic ability, noble sentiments and comprehensive development" [1].

Aesthetic education, as a form of education that imparts aesthetic concepts and aesthetic experience, has a significant impact on the growth of everyone and the harmonious development of society [2]. In recent years, the Chinese government has issued corresponding documents to ensure the implementation of aesthetic education. Therefore, certain progress has been made in related theoretical research and practical exploration. However, many universities, especially those of science and engineering, still have a weak awareness of aesthetic education.

Take university computer education as an example. This subject has strong professionalism for universities. The teaching of this subject focuses on cultivating students'

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professional and practical skills, so that students can use computers to discover, analyze and solve problems. However, whether it is in terms of teaching content, teaching process, or teaching quality evaluation, most universities at this stage teach in accordance with the examination syllabus, focusing on the transfer of knowledge and skills. Usually they ignore the role of aesthetics in teaching, paying little attention to design and communicate beauty during their teaching process. Moreover, many teachers of universities generally have a narrow concept of aesthetic education or insufficient understanding. They believe that aesthetic education is only art education, which is about music or fine arts. Some teachers even regard aesthetic education as philosophy, emphasizing theory and critical thinking, which have nothing to do with computer education. These understandings have neglected the intuitive and sensitive side of computer education itself. Actually, the education process combines the teaching of knowledge and the cultivation of students' healthy computer aesthetic awareness. Therefore, the implementation of aesthetic education has not been effective in many universities. This delays the practice of quality education and is not conducive to the cultivation of comprehensive high-quality scientific and technological talents.

1.2 The Perfect Function of Aesthetic Education in Computer Teaching

Aesthetics is a kind of instant "experience" for individuals to perceive their own life existence and the nature of the world. It is a cognitive model and a method of thinking which cultivates students' ability to recognize, appreciate and create beauty [3]. It itself is a dynamic and open system composed of countless aesthetic activities. The science and technology courses contain a large number of aesthetic phenomena in their contents. As a matter of fact, science and aesthetics are inseparable, their common foundation is human creativity. Furthermore, scientific research activities are processes of not only "seeking truth", but also "aesthetics". Therefore, digging out the aesthetic elements in science and technology from an aesthetic point of view will allow students to experience more, which can improve their subjective perceptions and cognitive abilities of computer technology [4].

Computers are the source of innovation and the specific medium of human activities. Take computer technology as an example, the teaching of this subject should strengthen the computer aesthetic education in classroom and practical teaching. Educators can try to create a teaching atmosphere based on computer aesthetics from various dimensions so that their teaching process is not merely a cold technical training, but also includes cultivation of their aesthetic awareness.

In conclusion, it is necessary to explore the aesthetic concepts of teaching content and methods in computer education. On the basis of these researches above, this paper proposes several strategies of integrating aesthetic education elements into computer teaching in colleges and universities from specific teaching links such as classroom, experiment and practice.

2 The Strategy of Integrating Aesthetic Education into University Computer Education Ease

To integrate aesthetic education into computer education, it is necessary to update the aesthetic education concepts of the most teachers in universities. It is significant for them to understand the indispensability of aesthetic education based on the requirements of the times. Teachers ought to establish their own aesthetic awareness in computer education. When setting teaching content and teaching links, they had better re-examine and re-explore the aesthetic characteristics of the curriculum. This is because only when educators broaden their horizon and change their original narrow opinions, could it be possible for them to guide students to discover and understand the scientific aesthetic logic in computer technology.

Due to the characteristics of computer science, computer courses generally include classroom learning, experimental processes and more practical links. Thus, the integration of aesthetic education into university computer teaching can be explored from three aspects, namely, classroom teaching, experimental guidance as well as practice promotion.

2.1 Beauty in Classroom Teaching

The French mathematician Henri Poincare once said: " The scientist does not study nature because it is useful; he studies it because he delights in it, and he delights in it because it is beautiful" [5].

Take computer science as an example, the subject is highly specialized and complex. The teaching content should not only cover comprehensive computer technical knowledge, but also be able to meet the students' demands of beauty. When teaching "true" knowledge, teachers ought to pay attention to digging out various aesthetic elements in the content. The aesthetic point of view of actual teaching content can be optimized from the following aspects.

Vividness. Aesthetic activities directly appeal to perceptual objects, which are inseparable from thinking in images. Computer teaching should develop students' observation, imagination and image thinking ability through more vivid teaching content and methods.

Computer courses require higher rational and logical thinking skills. But if teachers focus more on knowledge transferring, the process will be filled with the boring explanations of concepts, techniques, and operating procedures. As a result, student will gradually lose interest. To avoid such embarrassment, teachers need to develop more vivid teaching ability.

Vivid teaching is mainly embodied in two aspects: teaching content and its methods. The former means that teaching content should be integrated with the development of the times, social hot issues, major national projects and future development technologies.

For example, when teaching the evolution of computer programming languages, namely from primitive binary machine language to assembly language, from various popular high-level languages to 4GL languages, teachers can show students several typical cases written in specific different languages. This intuitive and perceptual comparison process will guide students to personally understand the aesthetic principle of the computer language. Also they will be inspired by the continuous pursuit of scientists in their struggle for better simplicity, efficiency, practicality and beauty.

In addition, vivid teaching is also reflected in teaching methods. Teachers should use advanced teaching methods to resolve teaching difficulties and devote themselves to creating a lively and relaxed teaching atmosphere. In psychology there is an important terminology called recency effect. It is a cognitive bias in which those items, ideas, or arguments that came last are remembered more clearly than those that came first. The more recently heard, the clearer something may exist in a juror's memory [6]. According to this effect, teachers should pay more attention to the current teaching links so as to maximize the teaching effect. From the aesthetic point of view, the teaching process is a kind of labor, which is a performance of intelligence and physical strength. In this way, teachers and students will inevitably form a relationship between aesthetic subject and aesthetic object. Teachers should devote to the pursuit of beauty during the specific process. They can demonstrate better teaching images, more pleasing expressions when trying to create more relaxed atmosphere.

Many software-related courses contain various algorithms, and some of them are abstract and difficult to understand. In this case, teachers can consider a visual teaching method, presenting some important algorithms or programming cases with vivid graphics and music programs. For example, teachers can design some works with exquisite interface and good logic for comparison and display. This way of comparison allows students to feel the beauty of computer design more vividly. It can not only deepen students' understanding of professional knowledge, but also stimulate students' enthusiasm and desire for practice.

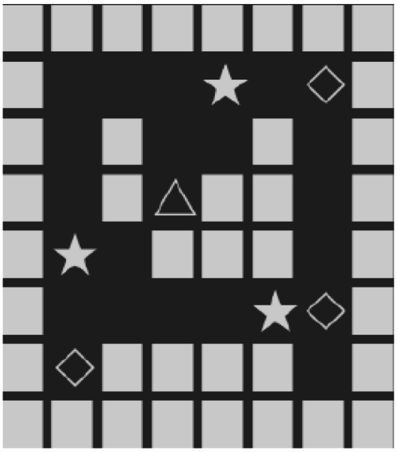

Fig. 1. The command line version of Sokoban

Taking the "Advanced Language Programming" as an example, when implementing C language applications, teachers can install easyX which is a plug-in of the common compilation environment called Visual Studio. For example, when explaining the graphic interface design by a two-dimensional array, teachers can introduce an interesting game

Fig. 2. Graphical version of Sokoban

called Sokoban and teach student how to implement this application. In advance teachers can design two versions for this game, namely the command line version (Fig. 1) and the graphical version (Fig. 2). Through these visual methods, students themselves will gain more curiosity and fun, which will inspire them to imitate and create more.

Pleasure. Dewey once said that most people only contact things through five senses. They like interesting things and show little interest in books [5]. The education of computer is more difficult, abstract, and boring. This puts forward higher requirements for teachers' aesthetic education. They will need more effective teaching methods to create a pleasant and interesting teaching atmosphere.

For example, in the computer software-related courses, teachers can consider using computer games as contents to cultivate students' interest. Taking the high-level language programming courses as an example, teachers can guide students to gradually develop games. By this mean students' interests, their programming skills will be developed. From this perspective, teachers are required to collect and design some effective scenarios and puzzle games such as gomoku, playing airplanes, finding differences, linking, minesweeping, etc. Being familiar with these games, students will feel excited and will be more willingly to discuss various details of design and programming with the teacher. This process will not only enliven the classroom atmosphere, help students quickly reach the best state of learning, but also will help to cultivate their innovative thinking. Figure 3 is a Gobang game designed by students, with complete functions and beautiful interface.

Fig. 3. Mine-sweeping game designed by students

Emotionality. Lenin said that without emotion, and there has never been a person who pursues truth and ideals [5]. Rational computer education should also focus on inspiring students' inner emotional experience, rather than mechanically cold technical training because emotional memories last longer than other memories. Thus, courses with emotional feeling will cultivate more on students' strong interests and their persistent study habits.

In actual teaching, university computer education can be deeply explored and integrated with aesthetic elements through various ways, such as collective lesson preparation, teaching seminars, experience exchanges, on-site teaching observations and other activities.

Take the "Advanced Language Programming" course as an example. In computer education, the development of computers must be taught, that is, the process from electron tubes, transistors, integrated circuits to large-scale integrated circuits. Teachers can vividly talk about the beauty of science, the perseverance of scientific and technological workers and the attitude of lifelong learning through video or audio materials. Teachers can count down those unforgettable typical historical moments, let students feel the indomitable beauty of scientific and technological workers, and inspire their determination and responsibility to serve the country.

2.2 Beauty in Experimental Teaching

Former Soviet educator Suhomlinsky said that cultivating the feeling of beauty is only one aspect of aesthetic qualities, and another important aspect is the creation of beauty. Marxist aesthetics also believes that the correct aesthetics comes from labor practice [5]. The related courses of computer education have one common principle, which says "Only by hands, you can learn the truth." Therefore, for most courses of computer education, experimental courses are also important parts of computer teaching.

The aesthetic perspective in practical teaching can be optimized from the following three aspects.

The Principle of Activity. The principle of activity means that the individual must participate in the activity. In terms of computer education, the experiments are generally divided into two types, verification and design experiments. During the processes of experiments, teachers should not only guide students to actively digest knowledge, improve their ability to analyze and solve problems independently, but also need to inspire students to pay more attention to the beautiful design of software products such as composition, layout, color and shape, and develop practical applications.

The Principle of Differentiation. The principle of differentiation requires teachers to design different angles for specific experimental content from a technical and aesthetic point of view. Different experiments have different focuses. Some focus on whether the design of the data structure and algorithms are the most concise, whether the time and space complexity are the lowest. Others focus on the visual aesthetics of their works, such as whether the layout is beautiful, the user interface is exquisite, or the operation process is humanized. This kind of conscious analysis and guidance will enable students to truly understand that a piece of perfect work is not only about its complete function, but also about its various aesthetic expressions. Under this influence, students will consciously use their aesthetic knowledge in their actual experimental performance. Thus they are easy to form their own unique design style and improving the quality of their works comprehensively.

	Sub-evaluation												
	Process evaluation (40%)						Functional evaluation (40%)			Aesthetic evaluation (20%)			
										Visual performance		Logical performance	
	Design	Coding	Debug	Test	Reply	Report	Sub-function 1	Sub-function 2	Sub-function 3	Interface layout	coding style	data	algorithm
Excellent													
Good													
Middle													
Qualified													
Unqualified													

Fig. 4. A specific evaluation form

The Principle of Creativity. The principle of creativity refers to cultivating students' performance ability, especially their imagination. In actual computer experimental courses, immersive education methods such as "teacher guidance, teacher-student interaction, and group discussion" can be adopted. In each link, by selecting excellent students' works, teachers will teach students how to appreciate its beauty form the perspective of their functional and aesthetic characteristics. This method will form a good atmosphere for the interaction between them and at the same time students will be inspired to create more beautiful works. Of course, after their experiments, a scientific evaluation system must be provided. Teacher assessment and collective evaluation can be used. Generally speaking, the evaluation system should be different because of the specific experimental content. It usually includes process evaluation, functional evaluation, and aesthetic evaluation. Only from all comprehensive aspects, students' ability can be evaluated more objectively and more accurately. Figure 4 shows the specific evaluation form of an experimental course.

2.3 Beauty in University Practice

Education is also influenced by the cultural of university. The computer education can not only to rely on classroom teaching and experimental teaching, but also pay more attention to cultivating students' practical aesthetic quality. When universities provide more practical activities, they should focus more on the aesthetic elements among them. In this way students will gradually regard it as a necessary way of social life, which helps to develop their intuitional practice of the professional knowledge.

Generally speaking, universities can share, display and propagate the aesthetic value of computer works through scientific and technological competitions, debates, club activities, lecture reports, online magazines, etc. At the same time, in this era of "Internet + ", big data, and AI intelligence, universities can integrate schools and social resources to achieve aesthetic education. For example, they can strengthen the interaction with related companies and establish the corresponding aesthetic education practice base.

3 Conclusion

It is very necessary to introduce aesthetic strategies in university computer teaching. Teachers can develop more methods through various teaching links such as classroom, experiment and practice. This kind of education not only makes computer teaching more vivid, but also enables students to gain correct and healthy aesthetic ability while mastering professional computer knowledge. Practice has proved that this strategies can improve the quality of computer education more comprehensively.

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A Study on Random Differentiation Methods for Homework Based on Fuzzy Test

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Abstract. A fuzzy test-based method for random differentiation of homework is proposed to address the problems of low update frequency, serious plagiarism and weakened barriers in university coursework. In order to generate fuzzy homework questions, a semi-automatic framework for fuzzy test-based homework is designed and the four key steps are described in formal language, including pre-processing, variable construction, variable screening and difficulty assessment. The effectiveness of the method is illustrated through a comparison of student teaching data, questionnaire feedback and faculty interviews in a pilot course on principles of computer composition.

Keywords: Homework Design · Fuzzy Test · Course Construction · Random Differentiation

1 Introduction

The Implementation Opinions on the Construction of First-class Undergraduate Curriculum (China Ministry of Education Higher Education Document No. 8 [2019]) pointed out that the curriculum system is the foundation, core and key to the quality assurance of talent cultivation [1] and that the construction of golden courses of "one degree in both genders" standard is inseparable from high-quality assignments. However, the fact is that homework in Chinese universities is generally not valued by teachers and students due to its weakness and inhibition, and lacks careful design, which has become the "short board of the curriculum" [2]. This is reflected in the low frequency of updating the homework question library, the high degree of similarity with online questions, and the single difficulty of the questions, which leads to students being keen to search for questions on the Internet, copy others' homework, and complete homework tests quickly and at the lowest cost, resulting in a serious decline in learning initiative.

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In order to solve the aforementioned problems of collegiate assignments, this paper proposes a semi-automatic fuzzy test-based coursework framework to provide students with personalised questions. After practical analysis, it can effectively enhance students' learning initiative by preventing similar questions, dynamically adjusting the difficulty level and allowing students to repeatedly self-test, and providing teachers with scientific data on the real learning situation.

2 Related Work

2.1 Innovation in Homework Questions

According to Bloom's cognitive model, knowledge can be divided into six types: remembering, understanding, applying, analysing, evaluating and creating [3]. Tan Xiaoxi [4] suggested that assignments are a tool that can connect teachers with students and students with each other in a dialogue, so researchers also think of ways to ensure that assignments are unique and expected to collect learning accurately so that remedial measures can be made in a timely manner to effectively enhance teaching and learning.

Since COVID-19 in 2020, more and more scholars have been innovating and making breakthroughs in the way homework is assigned and corrected. Li Jianzhang et al. [5] proposed to split large computational questions into multiple blanks and then use the pre-prepared conditions and answers in the database to customise the questions for students; Huang Hengjun [6] et al. used a housework system based on resampling techniques to achieve differentiated assignments at low cost and achieved good implementation results, but it was mainly used for data analysis courses as well as experimental data. It can be seen that the current functional requirements of university coursework systems are mainly focused on the ability to randomly vary, to repeatedly self-test, and to automatically correct, etc. Fuzzy testing techniques meet the needs of these precisely.

2.2 Fuzzy Test

Fuzzy testing is an automated software testing technique that is centred on the ability to automatically or semi-automatically provide random test cases as input to a target system that can be iteratively tested to expose the possible software vulnerabilities. Fuzzing refers to the automatic generation and execution of tests, and the random data input to a fuzz test is often referred to as 'Fuzz'.

Yang et al. [7] spent three years reporting over 325 vulnerabilities to developers of compiler community. 2019 Google Project Zero [8] reported the number of vulnerabilities found through fuzz testing, with a percentage of 37%, and fuzz testing has now become an important technique for detecting vulnerabilities in systems.

The basic workflow of fuzzy testing can be divided into 5 steps: Preprocessing, Input building, Input selection, Evaluation and Post-fuzzing. The first and fifth parts are the preparation work before the fuzzy test starts and the closing work after the fuzzy test is finished, while the actual test parts are the second to fourth parts.

3 Questions Design

3.1 Preprocessing

According to Bloom's cognitive model, in the core course Principles of Computer Composition for computer science, preprocessing adjusts the format of questions through human intervention to meet the requirements of automatic computer review and to limit the possibilities of student answers as much as possible.

For example, traditional calculation questions can be designed as step-by-step fill-in-the-blank questions, leaving blank content on each key step of the solution for students to fill in, or the calculation questions can be transformed into programming questions [9]. After this session each question E can be considered as a combination of items I, represented by the Eq. (1):

$$E = \{I_1, \ldots, I_n\}^T (n \geqslant 1) \tag{1}$$

where I consists of the sets, including templates T, variables V and relations S, as in the Eq. (2):

$$I = T + V + S(V, A) \tag{2}$$

S(V, A) represents the mapping relationship from the set of variables V to the set of answers A, i.e. each variable element v can be calculated in a fixed way to arrive at the corresponding answer a. It is noted that V(S) is the definition domain of the calculation relationship S, and A(S) is the value domain of the calculation relationship S. Therefore, when using the same template T, the larger the number of variables set V, the smaller the chance of identical answers, which can effectively reduce the possibility of plagiarism by students.

3.2 Variable Construction

The variable construction focuses on the random variation of input data in the correct format of the original question. The analysis of the characteristics of question types determines the types of importable variables, the allocation strategy and priority of the variables, and finally constructs some input data as initial test cases based on this information.

1) Types of judgement, choice questions

Judgement type E_{jdg} is formed by joining multiple terms $I_n (n \geq 1)$ by a Cartesian Product, noted as:

$$E_{jdg} = Product\{I_1, \ldots, I_n\} (n \geqslant 1) \tag{3}$$

By randomly generating Boolean variables V = {Yes, No}, A = {True, False}, it follows that I consists of a pair of positive and negative propositions, i.e. I = {P, ¬P}.

If |N| denotes the number of elements in a set, then the equation |Ejdg| = 2n indicates that there are 2n different combinations. For example, when n = 2, |Ejdg| = |I1 × I2| =

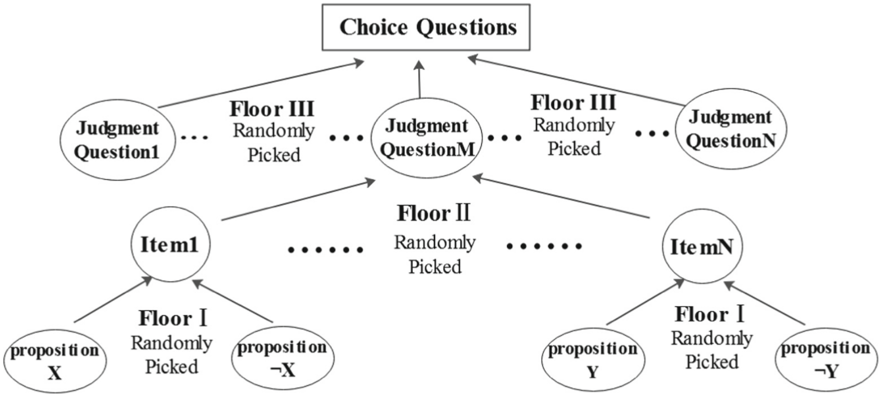

Fig. 1. Three-Floor random structure

$|\{X, \neg X\} \times \{Y, \neg Y\}| = 4$ expresses that students can make a judgement from 4 different descriptions of the question (Fig. 1).

Single and multiple choice questions are essentially the same in that they are made up of a number of judgement questions (3). The difference between the two lies in the number of combinations of options. Single-choice questions consist of the only correct or the only incorrect combination, whereas multiple-choice questions consist of two or more correct or incorrect combinations, which is expressed as:

$$E_{sch} = Select\ in\left\{E_{jdg1}, \ldots, E_{jdgn}\right\}\ \&\ |T\ or\ F| = 1 \quad (4)$$

$$E_{\mathrm{m}ch} = Select\ in\left\{E_{jdg1}, \ldots, E_{jdgn}\right\}\ \&\ |T\ or\ F| \geqslant 2 \quad (5)$$

Thus, whether it is a judgement, single or multiple choice question, multiple combinations of similar but different answers can be expressed through the construction of Boolean variables V, which are randomly assigned to students for completion as homework in the course. In addition, there is also a category of multiple choice questions which are answered by filling in numbers, which will be discussed along with the following.

2) Types of blank, calculation questions

Assuming that a computational relation S(V, A) exists in these questions, then in order to find $a \in A(S)$, we need to understand the definition description in T and then construct the computational model S based on the data condition $v \in V(S)$ given in the question, noted as:

$$\exists S(V, A), S : V|T \to A \quad (6)$$

In this case, the computational relationship S is the focus of the question, and the application of students' knowledge is repeatedly reinforced by constructing different data conditions v.

Questions allow for constructing one-dimensional vectors $\{V_1, V_2, \ldots, V_n\}^T$ to meet the demand of combinations of computational relationships. So students can randomly compute one of $\{A_1, A_2, \ldots, A_n\}^T$ and teachers can analyse the level of detail of students' knowledge. It is worth noting that there is a progressive or decentralised relationship between the computational relationships, depending on the need for a knowledge quiz.

3) Types of program cloze questions

The template T for this type of question is changed to a design diagram or procedure in which $V = \{b_1, \ldots, b_n\}$ are pre-designed in T. A number of blanks are randomly selected from V to form the set named B, while the set of other remaining blanks called V-B, is directly replaced by the corresponding answer AV-B, noted a

$$S : B|(T + A_{V-B}) \rightarrow A_B, T = \{Picture, Program\} \tag{7}$$

3.3 Variable Filtering

The input selection filters the constructed data and sets constraint policies. It tries to filter out invalid input data in advance, including conflicts such as data types, data ranges, repetitive or contradictory descriptions, and undefined behaviour of the compiler. And it guarantees the quality of the input data and the accuracy of the topic description.

There are various strategies for setting constraints, e.g. input data for some topics can be determined by comparing the results of multiple generic compiler runs, with all runs agreeing before passing; e.g. teachers can directly delineate the types of data that can be input and the range of data or teachers collect feedback from students on the vulnerabilities of assignment problems through the assignment platform and fix them.

3.4 Difficulty Evaluation

This part as the final step in the fuzzy test process, will select an appropriate assessment indicator for optimising a more rational strategy and reflecting students' true level of performance on knowledge. At this stage, current research has focused on the performance of the assignment on two indicators: the failure rate of the questions and the difficulty factor.

According to Bernoulli's law of large numbers, let nA be the number of times event A occurs in n independent repetitions. p is the probability of event A occurring in each trial, then for any positive number $\varepsilon > 0$, we have

$$\lim_{n\rightarrow\infty} P\left\{\left|\frac{n_A}{n} - P\right| < \varepsilon\right\} = 1 \tag{8}$$

Bernoulli's law of large numbers states that the frequency of an event nA/n converges to the probability of the event p. This means that when n is sufficiently large, there is little chance that the frequency of the event will deviate significantly from the probability. From the principle of practical extrapolation, the frequency of an event can be used in place of the probability of an event in practical applications where the number of trials is large.

Since the difficulty factor for each question is proportional to the probability of missing a mark, the difficulty factor can be obtained from the probability of missing a mark or the rate of missing a mark. Each question has a different probability of losing marks depending on the variables. If a mark scheme is used, the mark is lost if the answer is correct, and the mark loss rate for a particular assessment point is defined as the difficulty factor, which is given as:

$$P_{final} = P_{base} * \left(1 + P_{offset}\right) = \frac{N^e}{N} * \left(1 + \frac{N_v^e}{N_v}\right) \tag{9}$$

where N_v^e and N_v denote the cumulative number of missed scores and hits respectively for a question after adding a random variable (offset), N^e and N denote the cumulative number of missed scores and hits respectively for a question using the baseline condition, p_{base} and p_{offset} denote the rate of missed scores for a question using the baseline condition and the rate of missed scores for a question after adding a random variable (offset) respectively.

Sometimes a question often has more than one assessment point, so the difficulty factor of the question is defined as the average of the difficulty factors or probability of losing marks for all the assessment points of the question, i.e. the difficulty factor of a question with many assessment points, which is recorded as:

$$P_{avg} = \frac{1}{m} \sum\nolimits_{i=1}^{m} P_i \tag{10}$$

In the online assignment platform system, whenever a student submits an answer sheet, the system performs a self-study of the test results submitted by the candidate, i.e. recalculates the difficulty factor and modifies the difficulty factor of the corresponding test question to suit the actual solving ability of the current student. As the number of assignments and the number of assignments increases, the difficulty factor gradually approximates the actual situation.

4 Framework Design

The different types of questions consist of a variable V, a template T, and a mapping relation S(V, A). Obviously, homework questions can be generated in a program, where the variable <V> corresponds to the program input, the template <T> to the static content printed out by the program, the mapping relation <S> to the logical transformations in the program, and the answer <A> to the program output. In addition to this, the program incorporates a seed s for randomly generated variables and a constraint r. If the mapping relation S can be expressed by a simple formula, this can be achieved by using the Office/WPS Excel formula. The specific framework design for the homework is shown in Fig. 2.

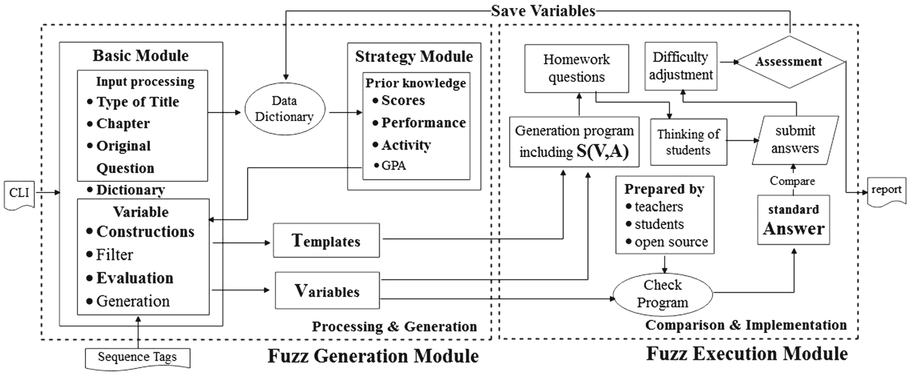

Fig. 2. Framework for semi-automated homework based on fuzzy test

The following are some details from Fig. 2:

- The teacher selects a particular question as the Parent Question after a number of assignment questions have been randomly generated through the same program. All the initial difficulty factors are obtained from databases or teachers.
- The system can be programmed to automatically judge answer sheets and update difficulty factor of each question.
- The assignments will be adaptively assigned to students based on the difficulty of the question and their past performance with as high a coverage as possible through the intelligent systems.

5 Teaching Effectiveness

5.1 Teaching Data Comparison

The teaching class of the pilot course on Principles of Computer Composition was divided into two groups, the control group (161 students) and the experimental group (161 students) both used the online platform to do the exercise. The difference is that each question in the control group is identical, and each question in the experimental group has the same origin, but different variables and answers.

It can be seen from Table 1 that the experimental group, after reinforcement with anti-plagiarism and self-testing of randomly differentiated homework, had significantly higher learning initiative, more communication and discussion, deeper understanding of knowledge points and higher achievement of course objectives than the control group.

Table 1. Data Comparison of Teaching Activities

Group	*E-Learning hours minute/person*	*Question completion question/person*	*Interaction activity times/person*	*Final Exam average score*
Cnt	433	215	24	62
Exp	667	392	35	78
Ratio (C/E)	64.9%	54.8%	68.6%	79.5%

5.2 Questionnaire Analysis

In order to investigate the effectiveness of the customised system of fuzzy test assignments from the perspective of the teaching class, regular questionnaires were administered to all students in both groups and the results showed that the majority of students had a positive opinion of the randomly selected question format.

In particular, a multiple-choice question that indicated a preference for the assignment was asked whether you would ask students directly "***What is the answer to this question***" or "***What is the process for this question***" when they did not know how to do the question, and over 90% of students of experimental group chose the latter.

6 Conclusion and Suggestion

In this paper, we use fuzzy test technology to build a course assignment platform, which automatically or semi-automatically generates random data into assignment templates by randomly varying the input data in the correct format of the original questions, and combining them into assignments with variant inputs for students to practice or take tests. The fuzzy mechanism for assignments both eliminates the majority of plagiarism by students and provides an efficient feedback mechanism for teachers and students, reinforcing the quality of teaching and learning, especially online.

But homework is still dependent on the core program that generates fuzzy data, and this requires a lot of programming effort on the part of the teacher. Therefore, future work will, consider lowering the threshold for using the coursework platform and studying the use of visualisation for the purpose of programming questions. These will continue to be studied in depth and continuously improved in subsequent work.

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Data Analysis on Characteristics and Current Situation of Faculty Teaching Development in Newly-Established Undergraduate Universities

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Abstract. Based on the index of faculty teaching development from 2000 to 2020, this paper analyzes the current situation of faculty teaching development in newly-established undergraduate universities from the aspects of region, province, school level and the composition of index. The research findings are as follows: the overall development of newly-established undergraduate universities is low, but there are many colleges with better development; Universities in east and northeast regions are better than those in middle and west regions, the development of each province is not sufficient and unbalanced; Universities with specialties in normal education, science, engineering and comprehensives perform better than others; there is a big gap between private and public universities; the teaching competition and teaching reform project are better than others among the dimensions of the index.

Keywords: Newly-established undergraduate university · Faculty teaching development · Data analysis

1 Introduction

With the continuous advancement of Chinese higher education reform, higher requirements are put forward for teachers' education and teaching level. Teachers' teaching development has gradually been highly valued by the competent education departments and universities [1–3]. Combing the relevant literature, it is found that there is less research on the evaluation of teachers' teaching development in the academic circle, and mainly focuses on the micro level discussion of teaching academic ability, teachers' teaching level, teaching methods and the improvement of teaching quality [4–6], and lacks the representation of teachers' teaching development at the macro level. Therefore, in 2018, China Association of Higher Education established an expert working group to systematically collect and sort out the achievements related to the development of Chinese higher education teachers in recent three decades, and developed a teacher teaching development index for domestic higher learning institutions. After combing

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and analyzing a large number of relevant documents, and on the basis of full investigation and soliciting opinions from many parties, the working group has constructed a "6 + 1" model of the national university teachers' teaching development index with clear boundary and connotation. The "6 + 1" model's primary indicators are: Teachers' team, teaching reform projects, teaching materials projects, teaching papers, teaching achievement awards, teachers' training base and teachers' teaching competitions, It also includes 41 secondary indicators and 93 tertiary indicators. Due to the huge amount of data, a large number of extreme data and unbalanced data structure in the teachers' teaching development index database, the idea of multiple iterative fitting of objective data and subjective evaluation is used for modeling. Descriptive statistics and entropy method are used in the objective evaluation. Analytic hierarchy process and Delphi method are mainly used in the subjective evaluation. 20 experts from the fields of pedagogy and educational management practice were invited to conduct several rounds of consultation. According to the repeated iterative fitting of experts' subjective opinions and objective data, the weight of university teachers' teaching development index system was determined. And it is verified that the index model is scientific from the perspective of Surveying through the analysis and test of reliability and validity [7, 8]. In May 2019, China Association of Higher Education released the first teaching development index of teachers in higher learning institutions in China[1]. The index is supported by objective data and reflects the teaching development of teachers in universities from the macro level [9].

Newly-established undergraduate universities, refers to those approved by the Ministry of education after 2000. As China's higher education becoming more and more popularized, the role of newly-established undergraduate universities can not be ignored. Although the importance of teachers' teaching development has been highlighted, the current research on Teachers' teaching in newly-established undergraduate universities is limited to the structure of teachers, teachers' professional level and teaching ability, and lacks an overall grasp of the state of teachers' teaching development in newly-established undergraduate universities. Based on the National Teachers' teaching development index of ordinary undergraduate universities from 2000 to 2020, this study uses SPSS 25.0 and Excel 2019 for data processing, statistical analysis and chart drawing. The specific research methods include descriptive statistics, difference comparison and other methods to analyze the current situation and characteristics of the teaching development of teachers in newly-established undergraduate universities in China, in order to provide reference for promoting the teaching development of teachers in newly-established undergraduate universities and improving the quality colleges.

2 Current Situation of Teachers' Teaching Development in Newly-Established Undergraduate Universities

With the demand of the popularization of higher education in China, the number of newly-established undergraduate universities continues to grow. From 2000 to 2020, the

[1] Consultation of China Association of Higher Education https://www.cahe.edu.cn/site/content/11952.html.

number of newly-established undergraduate universities increased rapidly from 62 to 675 (excluding vocational universities), accounting for 54% of ordinary undergraduate universities in China. From 2000 to 2020, 653 universities were listed in the teaching development index of newly-established undergraduate universities, with a listing rate of 96.7%. According to the economic region division standard of the National Bureau of statistics, it is divided into four regions: the east region, the northeast region, the middle region and the west region[2]. In the new undergraduate index from 2001 to 2020, there are 243 universities in the east region, with a listing rate of 96.8%; There are 56 universities in the northeast region, with a ranking rate of 94.9%; There are 189 colleges and universities in the middle region, with a listing rate of 98.4%; There are 165 universities in the west region, with a ranking rate of 95.4%. In general, the list of newly-established undergraduate universities in various regions covers a wide range, which can reflect the current situation of teachers' teaching development in newly-established undergraduate universities.

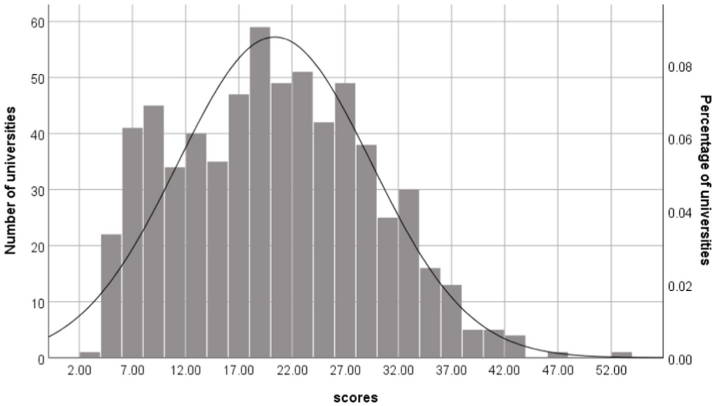

Fig. 1. Distribution of teachers' teaching development index in Newly-built undergraduate universities.

Based on the analysis of the National Teachers' teaching development index of ordinary undergraduate universities from 2000 to 2020, there are 1226 undergraduate universities on the list. If the first ranked Peking University scores 100 points, the highest score of newly-established undergraduate universities is 52.18 points, ranking 132 in the total list. Five newly-established undergraduate universities have entered the top 300, with a minimum score of 3.87, an average score of 20.37 and a standard deviation of 9.10. From the scores' distribution shown in Fig. 1, there are 11 universities with more than

[2] The east region includes: Beijing, Tianjin, Shanghai, Hebei, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong and Hainan; The northeast region includes Heilongjiang Province, Jilin Province and Liaoning Province; The middle region includes: Henan Province, Anhui Province, Jiangxi Province, Shanxi Province, Hubei Province and Hunan Province; The west region includes Chongqing, Sichuan, Shaanxi, Yunnan, Guizhou, Guangxi Zhuang Autonomous Region, Gansu, Qinghai, Ningxia Hui Autonomous Region, Tibet Autonomous Region, Xinjiang Uygur Autonomous Region and Inner Mongolia Autonomous Region.

40 scores, accounting for 1.68% of the total number of newly-established undergraduate universities in the ranking list, ranking among the top 350 in China. Most universities below 30 points (including 30 points), among which those with scores between 10–30 account for 67.99% of the total number of newly-established undergraduate universities in the ranking list. The teaching development index of teachers in newly-established undergraduate universities is generally low, but 11.9% of newly-established undergraduate universities score above the average score in the national ranking list, showing a good development trend.

3 Analysis on the Characteristics of Teachers' Teaching Development in Newly-Established Undergraduate Universities

Based on the National Teachers' teaching development index of ordinary undergraduate universities from 2000 to 2020, the outline of teachers' teaching development in newly-established universities was described from the aspects of regional, university-level and internal performance of the index, and its characteristics were explored to provide decision-making basis for further optimization of governance.

3.1 The Advantages of Teachers' Teaching Development in Universities in the East Region are Obvious

Divide according to the four regions of the east, northeast, west and west, and analyze the teaching development of teachers in newly-established undergraduate universities in each region (see Table 1). First look at the proportion of schools[3], from high to low, they are the east, middle, west and northeast regions, which are 37.04%, 28.44%, 25.78% and 8.74% respectively. For the proportion of total scores[4], the descending order is also the east, middle, west and northeast regions, which are 39.10%, 27.36%, 24.88% and 8.65% respectively. The total score of the east region is far ahead of other regions, and its total score proportion much is greater than that of other universities. Because of the differences in the number of universities in each region, the average school score is calculated[5]. The comparison shows that the east region still has obvious advantages, followed by the northeast region, and the west and the middle regions are relatively behind. Statistically, the number of top 100 universities accounted for 18.40% in the east region[6], which is much higher than other regions, followed by the northeast, the third in the middle region and the lowest in the west region. From the point of standard deviation, the standard deviation of newly-established undergraduate universities in the east and middle regions is relatively high.

[3] Divide the total number of newly-established undergraduate institutions in the region by the total number of newly-established undergraduate institutions.

[4] Divide the total score of the teacher development index of newly-established Undergraduate Colleges in the region by the total score of the teacher development index of newly-established undergraduate colleges.

[5] Divide the total score of the teacher development index of newly-established undergraduate institutions by the total number of newly-established undergraduate institutions in the region.

[6] Divide the number of colleges and universities in the top 100 of the new undergraduate universities index by the total number of new undergraduate universities in the region.

Table 1. Teaching development of teachers in newly-established undergraduate universities in different regions

Region	Number of universities	Percentage of universities (%)	Percentage of total score (%)	Average score of universities	Standard deviation	Percentage of entering top 100 of Newly-built undergraduate universities (%)
East	250	37.04	39.10	20.81	9.91	18.40
Middle	192	28.44	27.36	18.96	9.81	14.06
West	174	25.78	24.88	19.03	9.07	10.92
Northeast	59	8.74	8.65	19.51	9.56	13.56

The overall teaching development level of newly-established undergraduate universities in the east region is higher than that in other regions. The number of newly-established undergraduate universities with relatively good teaching development level accounts for a large proportion, mainly due to the developed economy in the east region of China, large overall investment in education funds, good teachers and high allocation of educational resources; Although the number of newly-established undergraduate universities in Northeast China is relatively small, the proportion of well-developed universities is quite large; The overall level of teachers' teaching development in newly-established undergraduate universities in the middle resion of China ranks last among the four regions, and the internal development is uneven; The teaching development of teachers in newly-established undergraduate universities in the west region is in a low-quality and balanced situation.

Calculating the average score and standard deviation of teachers' teaching development index of newly-established undergraduate universities in 29 provinces (cities and autonomous regions), take the average score as the vertical axis, the standard deviation as the horizontal axis, and the average value as the dividing line to draw a four quadrant diagram, as shown in Fig. 2. Starting from the upper left position, number the four quadrants into one, two, three and four in clockwise order. The average scores of universities in the first quadrant are higher than the average level, and the standard deviation is lower than the average level, indicating that the overall development trend of teachers' teaching level in these regions is good, and the internal development is relatively balanced. In this quadrant, the performance of Hainan Province is particularly eye-catching. The reasons are as follows: first, the number of newly-established undergraduate universities in the province is small, and the average scores of colleges and universities are high; On the other hand, according to the statistical announcement on the implementation of national education funds, the investment in education funds per student in higher education in Hainan Province has continued to increase in recent years. The characteristic of the second quadrant is that the average university score is higher than the average, but the standard deviation is relatively high. The teaching development level of newly-established undergraduate universities in these provinces is polarized, thus, the problem of internal development balance needs to be paid attention to. In the third quadrant, the overall level of teachers' teaching development is low, and the internal differences are large, and the problem of unbalanced development is also prominent. The average scores of universities in the fourth quadrant are low and the standard deviation is small. Although there is little difference in the teaching level of teachers in newly-established undergraduate universities in these regions, the low segmented universities gather, and the overall level needs to be improved.

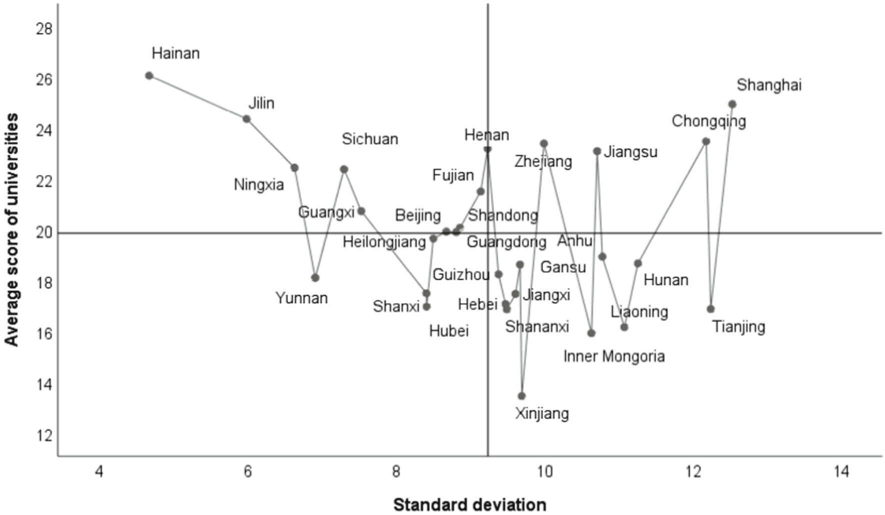

Fig. 2. Distribution map of average score and standard deviation of teachers' teaching development index in newly-established undergraduate universities in each province

The top 100 universities in the newly-established undergraduate universities index cover 25 provinces (cities and autonomous regions). According to the statistics of the number and percentage universities in each province, as shown in Fig. 3, the higher number of universities are Henan Province (12), Zhejiang Province (9), Jiangsu Province (8) and Shanghai (7), while Shanghai (38.9%) has the highest percentage of universities, followed by Chongqing (33.3%), and Zhejiang Province (32.2%) ranks third. Whether in terms of the number of the top 100 universities or the percentage of the number of universities, the east provinces represented by Shanghai and Zhejiang Province are better in the teaching development of teachers in newly-established undergraduate universities.

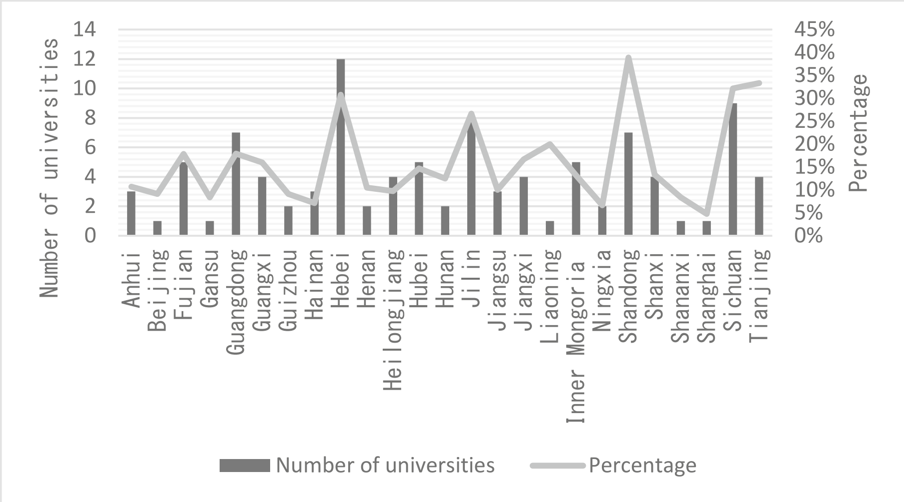

Fig. 3. Number and percentage of universities in the top 100 of the newly-established undergraduate universities index in all provinces

3.2 Analysis on the Characteristics of Teachers' Teaching Development at University Level

In order to study the teaching development of teachers in different types of schools, newly-established undergraduate universities are divided into six categories: science and technology, comprehensive universities, humanities and social sciences, normal universities, medical universities, agriculture and forestry. Relevant data are classified and counted, as shown in Table 2.

Firstly, in terms of the average scores of universities, normal universities, science and technology and comprehensive universities are higher than the average level, the humanities and social sciences are in the middle position, and the medical universities, agricultural and forestry with a small number of universities have low scores; For the standard deviation, the standard deviation of normal universities, humanities and social sciences and comprehensive university is small, and the standard deviation of science and engineering universities is the largest; Finally, in terms of the percentage of the top 100, the percentage of normal universities (23.40%) is much higher than that of other types of universities, followed by science and engineering (20.51%), the percentage of comprehensive and medical universities is in the middle, and the percentage of humanities and social sciences, agriculture and forestry universities is less than 10%. Based on the data analysis of the first three dimensions, among the newly-established undergraduate universities, teachers' teaching development in normal universities is the best, with small differences and balanced development universities; Science and engineering and comprehensive universities have an advantage in the number of universities and have a good overall development, but there are great differences within science and engineering universities, reflecting an unbalanced situation; Although there are a large number of Humanities and Social Sciences universities, the overall level of teachers' teaching development is weak; The number of medical and agricultural and forestry universities accounts for less than 7% of the newly-established undergraduate universities on the list. The total number of universities in the top 100 of the newly-established undergraduate index is only 4, which can be seen from the overall development level.

Table 2. Teaching development of teachers in different types of newly-established undergraduate universities

Type of universities	Number of universities	Average score of universities	Standard deviation	Percentage of entering top 100 of Newly-built undergraduate universities (%)
Science and engineering	195	20.51	10.38	20.51
Comprehensive	185	19.87	8.55	11.89
Humanities and social science	134	19.02	8.13	8.96
Normal	94	24.68	6.66	23.40
Medical	28	16.78	10.15	10.71
Agriculture and forestry	17	17.06	9.15	5.88

3.3 Analysis on the Development of Each Dimension of New Undergraduate University Index

The proportion of the score of each dimension in the teaching development index of newly-established universities was counted, as shown in Fig. 4. Observing the internal composition of index scores, it is found that the index scores of newly-established undergraduate universities are mainly distributed in three dimensions: teaching reform project, teachers' teaching competition and teachers' team, accounting for 69.58% of the total score, and the highest proportion is the teaching reform project (29.83%). The highest average index score of universities in China is also the teaching reform project, accounting for 30.65%, followed by the teacher team, accounting for 23.7%, and the proportion of teaching achievements ranks third (18.13%). The score of newly-established undergraduate universities in the dimension of teaching achievement award for 12%, while in the dimension of teacher teaching competition with high index score, the average index score of universities across the country accounts for only 10.36%, reflecting great differences.

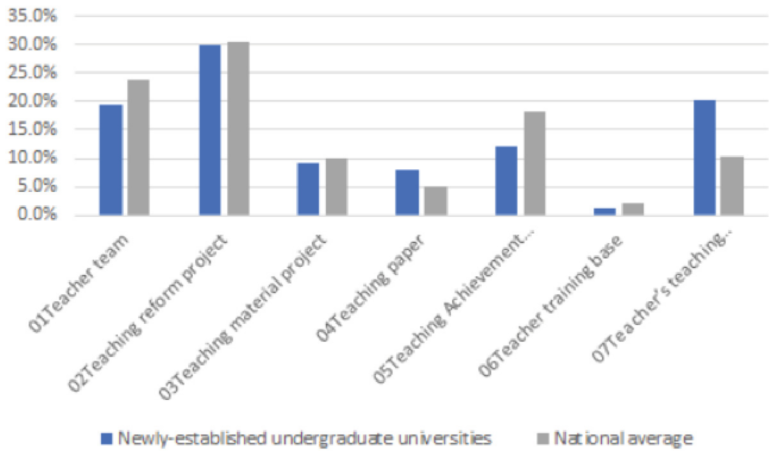

Fig. 4. Comparison of scores of each dimension

The normalized scores of each dimension of the teacher teaching development index were calculated respectively, and the score proportion of newly newly-established undergraduate universities in each dimension was counted (see Table 3). The teaching development index of teachers in newly-established undergraduate universities performs best in the dimension of teacher teaching competition, accounting for 33.46%, followed by teaching reform project, accounting for 33.28%. The scores of teacher training base and teaching achievement award are relatively low.

Table 3. Index contribution rate of newly-established undergraduate universities

Dimension	Normalized score of newly-built undergraduate universities	Normalized score of national universities	Percentage of scores of newly-built undergraduate universities (%)
Teacher team	8512.82	32700.75	26.03
Teaching reform project	13977.14	41997.08	33.28
Teaching material project	4444.88	22424.71	19.82
Teaching paper	10266.12	31753.98	32.33
Teaching achievement award	4402.39	24097.18	18.27
Teacher training base	1512.96	9719.93	15.57
Teacher's teaching competition	14063.11	42033.1	33.46

It can be seen that the teaching development of teachers in newly-established undergraduate universities focuses more on the micro level of teaching methods and teaching skills improvement, and also pays more attention to certain teaching research. There are shortcomings in the teacher training base and the refinement of teaching results. This not only needs to pay attention to accumulation, but also to seek a breakthrough in promoting the formation of characteristic achievements [10].

4 Conclusion

Based on the national teachers' teaching development index of ordinary undergraduate universities from 2000 to 2020, this study analyzes the characteristics of teachers' teaching development in newly-established undergraduate universities from multiple angles. On the whole, the teaching development index of newly-established undergraduate universities is mainly concentrated in low sections, which has not formed reasonable echelon, unreasonable hierarchy structure, and outstanding problems of inadequate development. From the regional perspective, the teaching development level of teachers in newly-established undergraduate universities in the east and northeast regions is higher than that in the middle and west regions, and the problem of unbalanced development between regions is prominent. From the perspective of university level, the teaching development level of teachers in newly-established normal and science and engineering universities is generally good, the comprehensive universities are at the medium level, and the teaching development level of teachers in agricultural and forestry, humanities and social sciences and medical universities is low. In terms of the composition of the index, the newly-established undergraduate universities account for a relatively high proportion of the scores of teachers' teaching competition and teaching reform project, and the teachers' teaching competition, teaching reform project and teaching paper make a relatively large contribution to the National Teachers' teaching development index.

The research on the theory of teachers' teaching development in China is relatively late, the practice of teachers' teaching development is in the exploratory stage, and the organizational structure of teaching development is not perfect. It is suggested to build a multi-level teacher teaching development training network, build a platform for teachers to communicate and share teaching, help teachers make career planning, guide teachers to conduct teaching academic research, etc., and improve teachers' teaching development level from multiple perspectives and in an all-round way [11]. There is a big gap between newly-built undergraduate universities and established undergraduate universities, and they belong to "vulnerable groups" in the competition of various resources. Therefore, the education management department should pay attention to the gap between newly-built universities and established universities, implement the hierarchical and classified management of colleges and universities, and increase the support for newly-built undergraduate universities, especially the economically backward areas in the middle and west regions. In various teaching achievement award, teaching reform project, teaching material construction and other projects at all levels, the method of classified evaluation and the combination of multiple evaluation such as process evaluation, value-added evaluation and comprehensive evaluation is adopted to evaluate not only the final results, but also the degree of effort and progress and development. So as to stimulate the enthusiasm of newly-built undergraduate colleges to accelerate the improvement of teachers' teaching development level, guide college teachers to return to their teaching responsibilities and awaken their endogenous awareness of teaching development. In this way, the driving force of teaching development will be continually generated [12].

At present, newly-established undergraduate universities have become an important part and main force of China's higher education. Promoting the teaching development of teachers in newly-established undergraduate universities is an urgent task for the connotative development of China's higher education in the new era. This study analyzes the current situation of teachers' teaching development in newly-established undergraduate universities, provides an empirical basis for teachers' teaching development in newly-established undergraduate universities to a certain extent, and provides a reference for further scientific evaluation of the educational development level of newly-established undergraduate universities and improving the quality of education.

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Exploration of Rose Curves with NetPad

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Abstract. Dynamic geometry system has been promoted actively in mathematical education because of its potential to comprehensively improve the core mathematical literacy required in an increasingly technology-based society. The ability to dynamically drag geometric elements to compare and discover relationships, and the ability to control movements and observe trajectory, are what make dynamic geometry system a powerful and efficient mathematical learning tool. This paper focuses on the application of dynamic geometry systems in inquiry-based maths education in middle school. Specifically, an inquiry-based learning activity named "mathematically drawing flowers with NetPad" is designed for students to study a characteristic feature of rose curves, i.e., the relationship between the number of petals and coefficient of rose curve equation. By sequentially graphing equations $\rho = A \cdot cos(n\theta)$ and $\rho = A \cdot cos(n\theta) + B$ with NetPad in a constructive way, and then observing, reasoning, verifying, and expressing, students can closely experience a complete generating process of maths knowledge, and further improve their innovation awareness and practical ability.

Keywords: Rose Curve · Dynamic Geometry · NetPad · Inquiry-Based Learning

1 Introduction

As a closed curve with various shapes, the rose curve has fascinated people since it was first studied by the Italian mathematician Guido Grandi in the 1700s. Moreover, mathematical properties and beauties of the rose curve have been practically applied in current industrial operations, such as orbital forming pressing, rope braiding, scanning, and weaving [1, 2]. Hence, topics about the rose curve gradually draw the attention of mathematical education in middle schools, especially inquiry-based mathematical education.

Instead of the lecture-based instructional approach, an inquiry-based mathematical learning activity refers to a student-centered and teacher-directed paradigm of teaching mathematics, in which students are expected to gain mathematical knowledge and further cultivate their innovation awareness by closely experiencing the generating process

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of mathematical knowledge, that is, finding and proposing meaningful mathematical problems, making a reasonable maths hypothesis, giving plans to solve problems, and arguing conclusions with mathematical ways [3–5]. According to a literature search, inquiry-based rose curve learning activities are mainly carried out by using physical tools or information technology. For example, Gao [6] proposes a STEM case in that students are guided to explore and physically draw a 4-petalled rose curve; Xu [7] proposes a case to explore the relationship between the number of petals and coefficient n of equation $\rho = A \cdot sin(n\theta)$ with a maths software; and Tuyetdong [8] further expands the exploration by drawing various rose curves in a dynamic geometry system. The maths nature of the 4-petalled rose curve is well demonstrated in Gao's case, and students are suggested to further draw other rose curves according to the same exploring method, it is an excellent example for applying the rose curve but not an efficient way to explore various rose curves because the drawing cost is relatively high. While in Xu and Tuyetdong's cases, properties of the rose curve are explored by observing different graphs, and graphs can be quickly plotted by introducing an equation and manipulating variables in dynamic geometry systems; although information technologies help saving more efforts, skipping the process and directly showing results after changing variables make the maths nature of the curves being hidden, and benefit of information technology tools are not fully utilized to affect learning behaviors [9–11].

In fact, the ability of dynamically dragging an object to compare and discover relationships while keeping the geometric constraints of the object unchanged is what makes a dynamic geometry system a powerful mathematical learning tool. In addition, users are allowed to interact with geometric objects and receive immediate visual responses to their actions; the interaction is beneficial in understanding, and the instant feedback of visualizing students' ideas and confirming or falsifying their assumptions will make problem solving more efficient [12, 13]. Hence, the availability of a dynamic geometry system allows some constructive ways that use the properties of rose curves to draw them. In particular, as a well-designed dynamic geometry system, NetPad has been widely accepted by middle school students and their teachers, barriers of technology acceptance are relative lower; moreover, the browser-based dynamic geometry system can be accessed from various terminals, which makes NetPad a convenient leaning tool [14–16].

Hence, this paper focuses on the application of dynamic geometry systems in inquiry-based maths education in middle school. A specific inquiry-based learning activity named "mathematically drawing flowers with NetPad" is designed for students to study a characteristic feature of rose curves, i.e., the number of petals. By graphing equations with NetPad in a constructive way, and then observing, reasoning, verifying and expressing, students are expected to closely experience the generating process of mathematical knowledge, and further cultivate their innovation awareness and practical ability. On the basis of students' prior knowledge about the polar coordinate system and cosine curve in the rectangular coordinate system, this activity is designed in the following four sections.

2 First Impression of Rose Curves

At the very beginning, teachers may assign a bridge-in task, i.e., observing and collecting shapes of flowers that students encounter in real life, expecting that they can extract several basic shapes similar to rose curves. Then, the rose curve is introduced as a tool for students to mathematically draw flowers having a desired number of petals.

Instead of directly providing static graphs or equations of rose curves, a more eye-catching way to impress and motivate students for subsequent learning is to present a generating process of a 4-petalled rose curve by means of a ladder model constructed in NetPad. As the course ware[1] shown in Fig. 1, radii *OA* and *OB* of circle *O* are perpendicular to each other; segments *CD*, *CE*, and *OF* are respectively perpendicular to segments *OA*, *OB*, and *ED*, then the trajectory of point F formed by dragging point *C* along circle *O* is the 4-petalled rose curve.

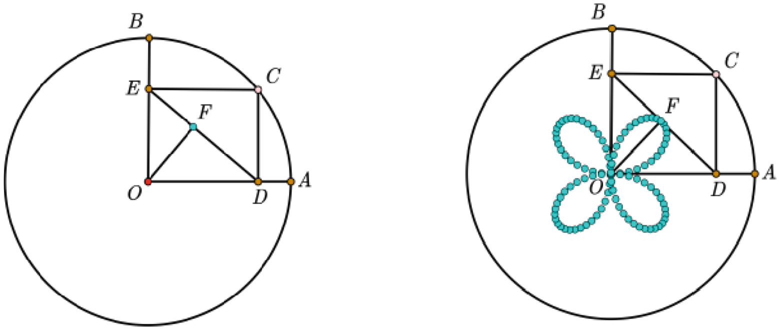

Fig. 1. Dynamically generating 4-petalled rose curve by dragging point *C*

On the basis of the model, there is a chance for students to creatively try and find how to change the number of petals by adjusting the model, such as what if radii *OA* and *OB* of circle *O* are not perpendicular to each other. Then, students can be encouraged to find the equation of the curve in polar coordinates. With point *O* as the pole, *OA* as the pole axis, $\angle AOF = \theta$, and it would not be difficult to get $OF = OD \cdot cos(\theta) = ED \cdot sin(\theta) \cdot cos(\theta) = OA/2 \cdot sin(2\theta)$. Obviously, the length of segment *OA* and coefficient of θ are keys that affect the graph. Hence, students would be motivated to see whether we can draw flowers having various numbers of petals according to equation $\rho = A \cdot sin(k\theta)$.

3 Constructively Graphing with NetPad

3.1 Inspire Students to Guess Based on Existing Knowledge

Since the fact that sine curve in rectangular coordinates corresponds to the horizontal coordinate and the central angle of a point moving around a circle, a model can be constructed to intuitively and dynamically show the generating process of the sine curve. As the courseware[2] shown in Fig. 2, point *A* moves along unit circle *C*, point C' moves along the x-axis at the speed of the value of the central angle of point *A*, line l_1 passes through point C' and is perpendicular to the x-axis, l_2 passes through point *A* and is

1 https://www.NetPad.net.cn/resource_web/course/#/479130.
2 https://www.NetPad.net.cn/resource_web/course/#/494350.

parallel to the x-axis, and then, the trajectory of cross-point B driven by points A and O' is the sine curve, which can appear bit by bit with the animation function.

By recalling the aforementioned existing knowledge, students may naturally come up with a logical idea: Is the graph of polar equation can be constructed by some points moved in certain forms?

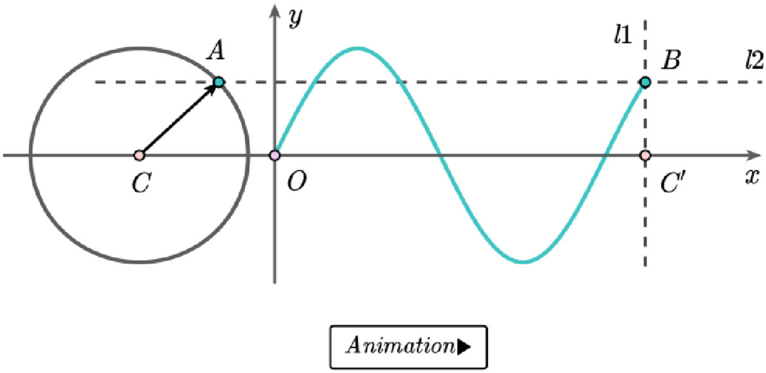

Fig. 2. Constructively graphing sine curve in rectangular coordinates

3.2 Analyze Equation

Students may directly analyze equation $\rho = A \cdot sin(k\theta)$, or analyze it after making some conversions. Because $\rho = A \cdot sin(k\theta) = A \cdot cos(k\theta - \pi/2)$, we know both $\rho = A \cdot sin(k\theta)$ and $\rho = A \cdot cos(k\theta)$ can be used to specify the rose curve, and a more generalized form is $\rho = A \cdot sin(\omega\theta + \varphi)$ or $\rho = A \cdot cos(\omega\theta + \varphi)$. For simpler calculation in the following part, here we suggest students adopt the polar equation $\rho = A \cdot cos(\omega\theta + \varphi)$.

Since students are more familiar with the rectangular coordinate system, they may wonder what happens if polar equation $\rho = A \cdot cos(\omega\theta + \varphi)$ is transformed into parametric equations in the rectangular coordinate system, that is:

$$\begin{cases} x = A \cdot cos(\omega\theta + \varphi) \cdot cos\theta \\ y = A \cdot cos(\omega\theta + \varphi) \cdot sin\theta \end{cases} \tag{1}$$

After being subjected to simple trigonometric conversions, Eq. (1) is organized into:

$$\begin{cases} x = \frac{A}{2}[cos((\omega + 1)\theta + \varphi) + cos((1 - \omega)\theta - \varphi)] \\ y = \frac{A}{2}[sin((\omega + 1)\theta + \varphi) + sin((1 - \omega)\theta - \varphi)] \end{cases} \tag{2}$$

The interesting thing is that parametric equations of two circular motions appear, as shown in Eq. (3) and Eq. (4). The two circular motions have the same radius, different moving speeds, and different phrase angles. That is, the graph of equation $\rho = A \cdot cos(\omega\theta + \varphi)$ is formed by a point in two different circular motions.

$$\begin{cases} x = \frac{A}{2}cos((\omega + 1)\theta + \varphi) \\ y = \frac{A}{2}sin((\omega + 1)\theta + \varphi) \end{cases} \tag{3}$$

$$\begin{cases} x = \frac{A}{2}cos((1 - \omega)\theta - \varphi) \\ y = \frac{A}{2}sin((1 - \omega)\theta - \varphi) \end{cases} \tag{4}$$

3.3 Construct Models

According to the geometric meaning of Eqs. (3) and (4), students can creatively construct a model to demonstrate the movement of a point driven by two circular motions in NetPad. A hint is the relative positions of two circular motions in the plane.

When points are running on two circles lying outside each other, the middle point of a segment connecting the two points satisfies our expectation; but the size of the graph seems not right due to a scaling effect. As the courseware[3] shown in Fig. 3, points A_1 and A_2 are respectively set to move according to Eqs. (3) and (4), then the trajectory of middle point M of segment A_1A_2 is a 4-petalled rose curve, but in the half size of the graph specified by the corresponding equations.

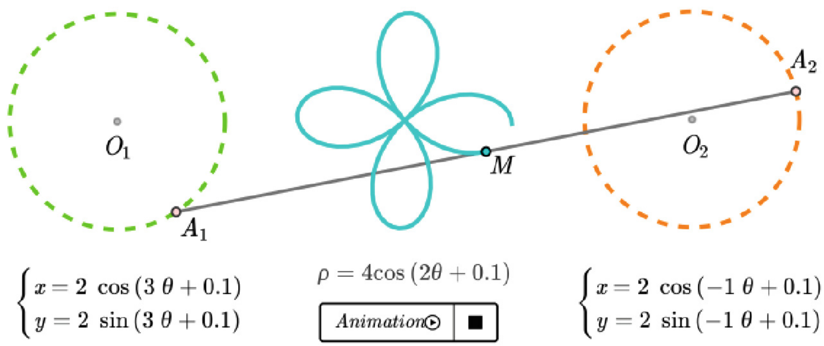

Fig. 3. A model based on separated circular motions

Then, students may consider a model containing tangent circular motions. As shown in Fig. 4, when circle O_2 externally or internally moves along circle O_1 in a tangent way, fixed point A on circle O_1 will make a circular motion too; and if fixed point A also moves along circle O_2, then point A is driven by two circular motions, and the movement of point A is just what we need. Obviously, no matter the externally tangent

[3] https://www.netpad.net.cn/resource_web/course/#/533753.

circular motions or internally tangent circular motions, the movement of the center of the running circle matters, leading that the tangent circular motions can be classified into secant circular motions, as shown in Fig. 4.

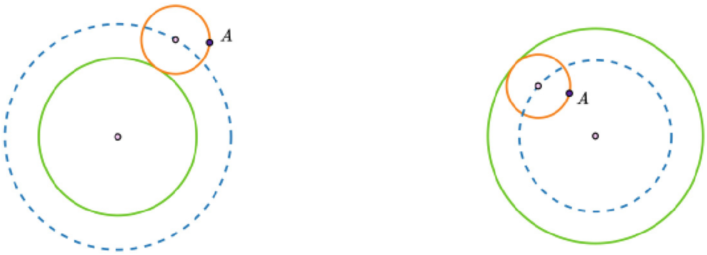

Fig. 4. A model based on tangent circular motions

More specifically, the external and internal movements can be rolling with or without slipping. For the case without slipping, it may not always draw the rose curve. In fact, this model is the key to the ladder model, students can try to find out the two circular motions hidden in the ladder model after this inquiry-based learning activity, and then, with the rule of the number of petals, various rose curve can be drawn according to the ladder model.

For the model of two secant circular motions, as the courseware[4] shown in Fig. 5, point O_2 moves along circle O_1 according to Eq. (3), point A moves along circle O_2 according to Eq. (4), and the trajectory of point A is the curve specified by the equation with specific parameters.

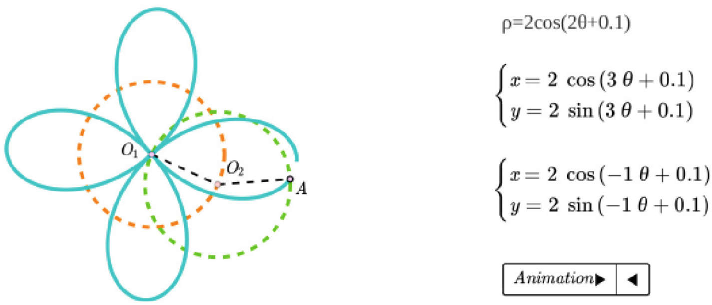

Fig. 5. A model based on secant circular motions

3.4 Parameter Settings

On the basis of the preliminary geometric construction, we will further set corresponding animation parameters by observing, analyzing, and expressing the ranges and geometric meanings of parameters A, ω, and φ.

4 https://www.NetPad.net.cn/resource_web/course/#/533774.

Obviously, the value of "A" refers to the sum of radii of the two circles or the farthest distance away from the pole, so "A" can be any real number. Extreme values A or −A is reached when $x = (kpi - \varphi)/\omega$, where (k ∈ Z); and one extreme value corresponds to a petal. The whole graph axially stretches from the pole as parameter A increasing, and parameter "A" only affects the size of the graph.

With different "φ", points start to move at different positions, causing the whole graph rotates about the pole at a certain angle. Meanwhile, by recalling corresponding knowledge about cosine curve in the rectangular coordinate system, students can draw the conclusion that the parameter "φ" decides the phase angle φ/ω of the initial phase, and "φ" can be a real number. Hence, the rose curve rotates at an angle of $-\varphi/\omega$ according to "φ", and "φ" does not affect the shape of the whole graph.

By observing the construction with different "ω", students would find out that points run at different speeds, and various numbers of petals appear. By referring to the period of the cosine curve in the rectangular coordinate system (the length of the period is 2pi/ω, the interval of the period is [−φ/ω + 2kpi/ω, (2pi − φ)/ω + 2kpi/ω)], (k ∈ Z), and ω ∈ R), students can set θ ∈ [−φ/ω, (2pi − φ)/ω), θ ∈ [−φ/ω, (2pi − φ)/ω + 2pi/ω)… to see what the graph of $\rho = A \cdot cos(\omega\theta + \varphi)$ looks like.

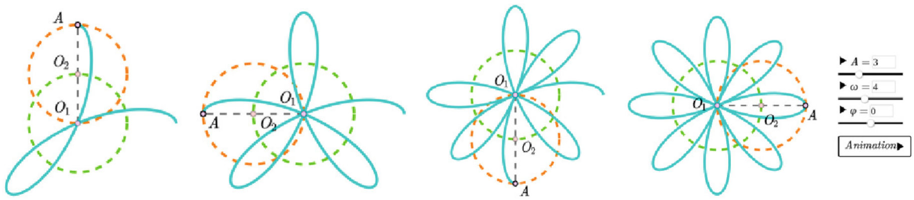

Fig. 6. Petals corresponding to different periods

As shown in Fig. 6, there are "two complete petals" in one period, "four" in two periods, "six" in three periods…. Since the rose curve is a closed curve, if there are just P complete periods (2pi/ω) within an interval of Q * 2pi, then the rose curve is closed (where P and Q are irreducible integers). That is, $P * 2pi/\omega = Q * 2pi$, i.e., $\omega = P/Q$; and "ω" should be set as a rational number for the graph of polar equation $\rho = A \cdot cos(\omega\theta + \varphi)$, which also can be represented as $\rho = A \cdot cos(\frac{P}{Q}\theta + \varphi)$.

According to the aforementioned analysis, students may choose their own model, we get the model containing "two secant circular motions" and corresponding parameter ranges, as the courseware[5] shown in Fig. 7. On the basis of the model, students can further dig the most characteristic feature of the rose curve, i.e., the number of petals, so as to draw various flowers mathematically as they like.

5 https://www.NetPad.net.cn/resource_web/course/#/536844.

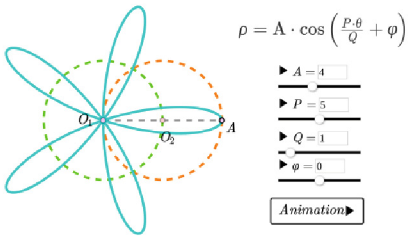

Fig. 7. The model of "secant circular motions"

4 Explore the Characteristic Feature - Petals

4.1 Draw More Rose Curves, Observe and Summary

On the basis of the aforementioned construction, students can draw more graphs by dragging the sliders and observe the relationship between the coefficient and the number of petals, as shown in Fig. 8.

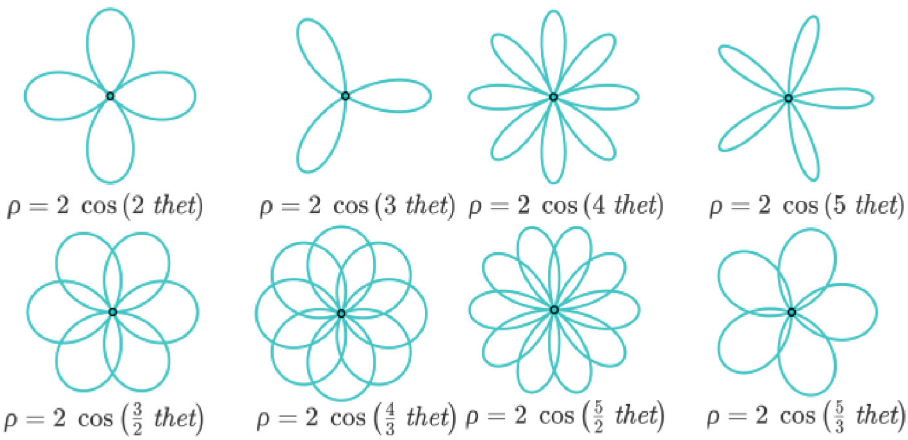

Fig. 8. Rose curves with various petals

Following facts would be easily got:

- The petals do not partly overlap with each other when P/Q is an integer; and the petals partly overlapped with each other when P/Q is a fraction.
- There are P petals when P/Q is odd, and there are 2P petals when P/Q is even.
- For a fraction P/Q, there are 2P petals when only one of P and Q is even, and there are P petals when both P and Q are odd.

To find out why, we can list out the polar coordinates for each peak by taking the equation $\rho = A \cdot cos(\frac{P}{Q}\theta + \varphi)$ as an example. All peaks are numbered from 0 to 2P-1;

peaks can be reached when θ = −φ/ω, (pi − φ)/ω, (2pi − φ)/ω, (3pi − φ)/ω, (4pi − φ)/ω…; and polar coordinates of each peak can be listed as (A, − φ/ω), (−A, (2pi − φ)/ω), (A, (3pi − φ)/ω), (−A, (4pi − φ)/ω)…. Moreover, in the polar coordinate system, a point with a negative radius is exactly the same point as one with the same positive radius, but in the opposite direction from the pole, that is, (−a, θ) is the same point as (a, θ + pi). Thus, our list of the peaks of the rose curve can be organized into Table 1.

Obviously, for even P, Q only can be odd, and the last P peaks do not overlap the first P petals; for odd P, Q could be even or odd, when Q is an even number, the last P peaks do not overlap the first P petals, and when Q is an odd number, last P peaks overlap the first P petals. Meanwhile, students can find the rule of the period of the whole graph, that is, when only one of P and Q is even, the period is 2Q * pi, or the period is Q * pi.

Table 1. List of Peaks

N^{th} peak	θ	Peak Coordinate		Organized Peak Coordinate	
0	$-\frac{\varphi}{\omega}$	$(A, -\frac{\varphi}{\omega})$		$(A, -\frac{\varphi}{\omega})$	
1	$\frac{\pi-\varphi}{\omega}$	$(A, \frac{\pi-\varphi}{\omega}+\pi)$		$(A, \frac{\pi}{\omega}-\frac{\varphi}{\omega}+\pi)$	
2	$\frac{2\pi-\varphi}{\omega}$	$(A, \frac{2\pi-\varphi}{\omega})$		$(A, \frac{2\pi}{\omega}-\frac{\varphi}{\omega})$	
...	...	...		...	
		Even P	**Odd P**	**Even P**	**Odd P**
P − 1	$\frac{(P-1)\pi-\varphi}{\omega}$	$(A, \frac{(P-1)\pi-\varphi}{\omega}+\pi)$	$(A, \frac{(P-1)\pi-\varphi}{\omega})$	$(A, Q\pi-\frac{\pi}{\omega}-\frac{\varphi}{\omega}+\pi)$	$(A, Q\pi-\frac{\pi}{\omega}-\frac{\varphi}{\omega})$
P	$\frac{P\pi-\varphi}{\omega}$	$(A, \frac{P\pi-\varphi}{\omega})$	$(A, \frac{P\pi-\varphi}{\omega}+\pi)$	$(A, Q\pi-\frac{\varphi}{\omega})$	$(A, Q\pi-\frac{\varphi}{\omega}+\pi)$
P+1	$\frac{(P+1)\pi-\varphi}{\omega}$	$(A, \frac{(P+1)\pi-\varphi}{\omega}+\pi)$	$(A, \frac{(P+1)\pi-\varphi}{\omega})$	$(A, Q\pi+\frac{\pi}{\omega}-\frac{\varphi}{\omega}+\pi)$	$(A, Q\pi+\frac{\pi}{\omega}-\frac{\varphi}{\omega})$
P+2	$\frac{(P+2)\pi-\varphi}{\omega}$	$(A, \frac{(P+2)\pi-\varphi}{\omega})$	$(A, \frac{(P+2)\pi-\varphi}{\omega}+\pi)$	$(A, Q\pi+\frac{2\pi}{\omega}-\frac{\varphi}{\omega}+\pi)$	$(A, Q\pi+\frac{2\pi}{\omega}-\frac{\varphi}{\omega})$
...	...	...	...	...	...
2P-1	$\frac{(2P-1)\pi-\varphi}{\omega}$	$(A, \frac{(2P-1)\pi-\varphi}{\omega}+\pi)$		$(A, 2Q\pi-\frac{\pi}{\omega}-\frac{\varphi}{\omega}+\pi)$	

4.2 Raise a New Question

After analyzing the effects of parameters P and Q, we can draw flowers having an expected number of petals according to the rule. However, it seems that we can draw any flower but a flower that, petals of which do not partly overlap with each other, and the number of the petals is an even number but not a multiple of four, such as six petals, ten petals and so on (Fig. 9). Shall we make a further step to make it out? Of course, but we need to go back to the very beginning, that is, the equation.

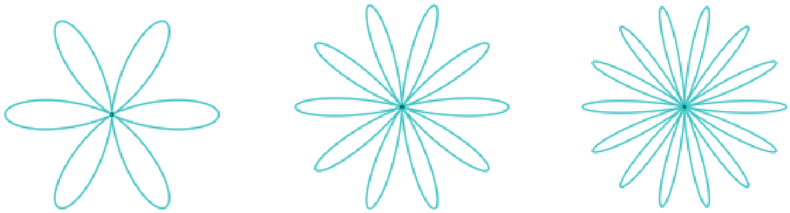

Fig. 9. Flowers cannot be generated according to equation $\rho = A \cdot cos(\omega\theta + \varphi)$

5 Draw the Generalized Rose Curve

Since a more generalized form of $y = A \cdot cos(\omega x + \varphi)$ is $y = A \cdot cos(\omega x + \varphi) + B$ in the rectangular coordinate system, we are inspired to explore the more generalized form of cosine curve $\rho = A \cdot cos(\omega\theta + \varphi) + B$ in the polar system.

5.1 Analyze and Graph Equation $\rho = A \cdot cos(\omega\theta + \varphi) + B$

The first step is also to analyze the equation and find out whether the graph of the polar equation $\rho = A \cdot cos(\omega\theta + \varphi) + B$ is generated by some points moved in certain forms. By transforming it to rectangular coordinate form, converting, and organizing, the polar equation $\rho = A \cdot cos(\omega\theta + \varphi) + B$ is converted into the following form:

$$\begin{cases} x = \frac{A}{2}[cos((\frac{P}{Q} + 1)\theta + \varphi) + cos((1 - \frac{P}{Q})\theta - \varphi)] + B \cdot cos\theta \\ y = \frac{A}{2}[sin((\frac{P}{Q} + 1)\theta + \varphi) + sin((1 - \frac{P}{Q})\theta - \varphi)] + B \cdot sin\theta \end{cases} \tag{5}$$

According to the equations, the graph is generated by a point driven by a sum of three different circular motions, and the circular motions have different radius, moving speeds, and phrase angles. Based on the previous exploration experience, or by referring to the scenarios of three circular motions that occur in life, such as the moon travels around the earth while they together travel around the sun, students can construct the model[6] shown in Fig. 10: with the animation function provided by Nepad, point O_2 moves according to the equation in light green, point O_3 moves according to the equation in dark green, and point A moves according to the equation in orange, where A ∈ R, B ∈ R, P ∈ N, Q ∈ N, and φ ∈ [0, 2pi).

5.2 Observe and Summarize Effects of Parameters

On the basis of the aforementioned construction, it is obvious that the length of the petal is A + B or A − B, which exactly corresponds to extreme values of equation $\rho = A \cdot cos(\omega\theta + \varphi) + B$. The interesting thing is that, if |A| > |B|, there are small petals generated in different directions, then students would be motivated to observe and make a classified discussion about how A and B affect the petals. Since the parameter B only determines the size of the curve so it can be a real number.

6 https://www.NetPad.net.cn/resource_web/course/#/496307.

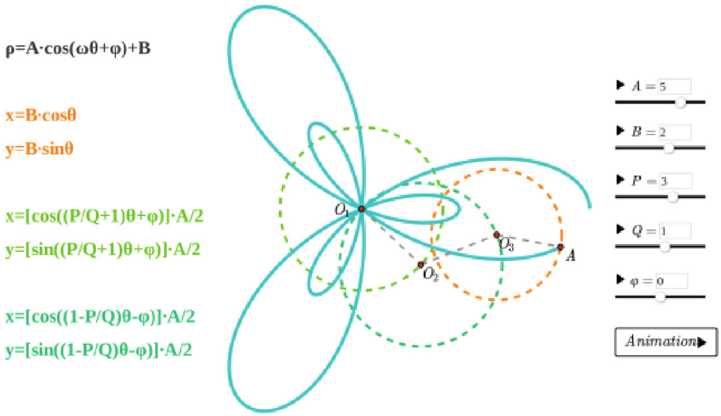

Fig. 10. A model according to equation $\rho = A \cdot \cos(\omega\theta + \varphi) + B$ (Color figure online)

- $|A| < |B|$: petals are not gathered together at one point but connected inwards a circle of diameter $|A - B|$ and outwards a circle of diameter $|A + B|$, shown in Fig. 11.

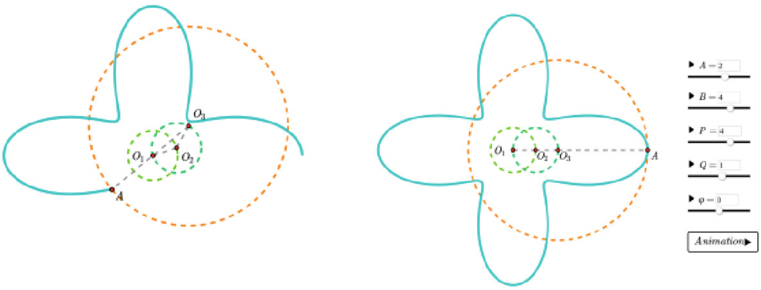

Fig. 11. A case when $|A| < |B|$

- $|A| = |B|$: petals are gathered together at a point and connected outwards a circle of diameter $A + B$, as shown in Fig. 12.

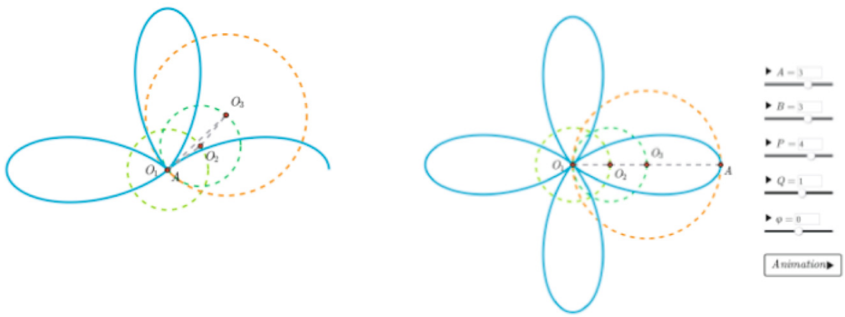

Fig. 12. A case when |A| = |B|

- |A| > |B|: there are smaller petals and bigger petals, all petals are gathered together at a point, but smaller petals are connected outwards a circle of diameter |A − B| and bigger petals are connected outwards a circle of diameter |A + B|, as shown in Fig. 13. In addition, all petals have the same size when B = 0, this is exactly the situation of $\rho = A \cdot cos(\omega\theta + \varphi)$.

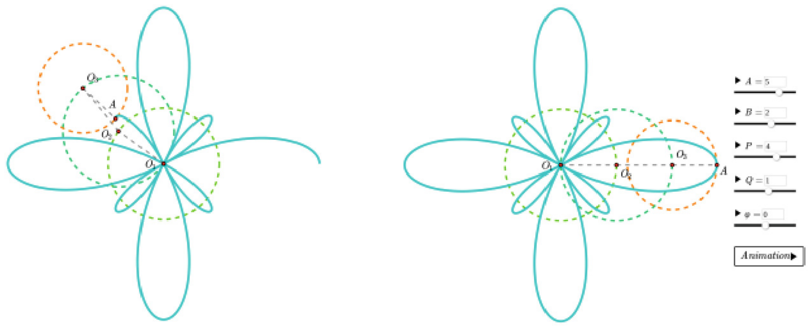

Fig. 13. A case when |A| > |B|

On the basis above, students can observe and summarize by graphing various rose curves, and finally draw a conclusion shown in Table 2. With this exploring process, they can mathematically draw flowers having desired number and shape of petals.

Table 2. Rules of Number and Shapes of Petals

<table>
<tr><th colspan="2">P/Q</th><th>|A|=<|B|</th><th>|A|>|B|</th><th>|B|=0</th></tr>
<tr><td rowspan="2">P/Q=integer
Petals without overlap</td><td>P/Q=odd</td><td>P petals</td><td>2P petals</td><td>P petals</td></tr>
<tr><td>P/Q=even</td><td>P petals</td><td>2P petals</td><td>2P petals</td></tr>
<tr><td rowspan="2">P/Q=fraction
Petals with overlap</td><td>P=odd & Q=odd</td><td>P petals</td><td>2P petals</td><td>P petals</td></tr>
<tr><td>P=even or Q=even</td><td>P petals</td><td>2P petals</td><td>2P petals</td></tr>
</table>

*For different values of P, Q, A, and B, the number of petals (in blue) are different

6 Conclusion

This learning activity explores the correspondence between the number of petals and parameters of the equation, by personally experiencing the whole process of discovering mathematical knowledge in the classroom with the support of information technology, students not only master the specific mathematical knowledge but also develop their mathematical learning and exploring skills.

Specifically, on the basis of students' prior knowledge about the method of constructively graphing cosine equations in rectangular coordinates system, they are encouraged to constructively graph polar equation $\rho = Acos(\omega\theta + \varphi)$ with analogical, associative, and innovative abilities, thus geometric meanings of parameters in the polar coordinate equation can be intuitively and profound understood after the constructive operations; furthermore, by graphing a number of rose curves, students observe, summary, express, and verify the rule of the petals; meanwhile, a new problem is raised, i.e., there are still some graphs that cannot be drawn, by logically guessing, students are motivated to graph polar equation $\rho = Acos(\omega\theta + \varphi)$ with the similar constructive method in NetPad, and finally draw a more complete conclusion about the rule of the petals. At last, students achieve the goal of mathematically drawing various flowers having the desired number of petals, during which they can experience the thinking and process of mathematicians inventing or discovering new knowledge, and further develop their innovation awareness and practical ability.

At the same time, information technology, as a beneficial tool for mathematical inquiry learning, provides a very ideal environment for students to actively discover and explore problems. As in the activity, students can creatively draw and set different circular motions to graph equation $\rho = Acos(\omega\theta + \varphi)$, conveniently observe various graphs by dragging variable sliders, and quickly reconstruct a model to graph equation $\rho = Acos(\omega\theta + \varphi) + B$. Furthermore, students can explore the two circular motions in the ladder model after this activity, and further draw various rose curves based on the ladder model. Hence, there is a larger space provided for students to practice or realize their ideas by doing mathematical experiments on NetPad, so that they can obtain real mathematical experiences rather than abstract mathematical conclusions. NetPad, an information technology that is deeply associated with maths subjects, balances abstract thinking and visual thinking, hands-on operation and mental work, as well as independent thinking and cooperative communication, making maths learning a more complete cognitive process. Moreover, the use of information technology does not cover up the thinking process, but constructively dissects the geometric principles, further making it a proper foundation for STEM education, etc.

In the future, it is expected to carry out a formal empirical study, so as to compare with traditional inquiry-based maths learning, quantitatively analyze the specific impact of information technology on inquiry-based mathematics learning, and evaluate students' exactly learning outcomes.

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The Construction of Python Advanced Computing Virtual Teaching and Research Laboratory

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Abstract. This paper analyzed the status and problems of Python curriculum across China at present, introduced the virtual teaching and research laboratory program launched by the Ministry of Education, and designed the construction scheme of Python Advanced Computing virtual teaching & research laboratory. The virtual laboratory provides a platform for teachers across the country to share abundant teaching and research resources, and jointly carry out teaching and research activities which can improve the quality of teaching. The virtual laboratory proposed in this paper can integrate the strength of college teachers across the country, improve teachers' teaching & research ability, and thus assist to cultivate students' computational thinking ability.

Keywords: Python · Virtual Teaching & Research Laboratory · Teaching Resource sharing

1 Introduction

At present, among all the general-purpose programming languages, Python, concerned mainly with computational problem solving, is the closest to the natural language. Its lightweight syntax and high-level language representation expresses the computational thinking concept [1].

In fact, Python, with its concise syntax, strong gluing of modules, and rich third-party resources in various technical fields, has become one of the most popular programming languages all around the world. In the past few years, Python has been chosen by more and more colleges and universities as the introductory programming language course for non-computer majors. In the courses offered by various universities and online teaching platforms, a number of excellent teachers and course resources can be found.

In the "Internet +" era, online and offline blending teaching has become a popular teaching mode [2, 3]. Many teachers make beneficial attempts to take advantage of various teaching platforms such as MOOC, SPOC, Rain Classroom, Python123, for teaching reform, and accumulated rich experience.

How to make full use of the existed abundant teaching resources, how to integrate various strength to produce more excellent teaching resources, and how to promote the

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experience of excellent teachers and put their advanced teaching concepts into practice, is the focus of this study.

2 Backgrounds

2.1 Python Teaching Status

In China, Beijing Institute of Technology started to offer Python program design courses for non-computer majors at the earliest in 2013. In recent years, Python has become a hot topic of teaching reform. More than 20 courses related to Python, given by many universities including Beijing Institute of Technology, have been opened on the MOOC platform [4].

During the process of curriculum development, a number of excellent teachers and course resources have emerged, including textbooks, teaching cases, experiment designs, etc. With the popularization of online and offline blending teaching modes, various platforms and tools have been used in course teaching, such as MOOC, SPOC, Rain Classroom, Python123. Some effective teaching methods have been explored and played a great role in cultivating students' computational thinking ability.

According to the statistics of Smart Education of China Higher Education Platform [5], among all the courses opened online, PYTHON PROGRAMMNIG, given by Mr. Tian Song from Beijing Institute of Technology, is the most popular one. It has been opened for 17 times on MOOC online platform, and the total number of students has exceeded 4 million. Another two curriculums, PYTHON WEB CRAWLER AND INFORMATION EXTRACTION and PYTHON DATA ANALYSIS AND PRESENTATION have accumulated more than 600,000 and 400,000 enrolments respectively.

However, the curriculum practice of Python has not been carried out for a long time and the development situation is very uneven. In most of the universities and colleges, compared with other traditional courses, the development of Python curriculum is still faced with the problem of lack of experience and shortage of professional teachers, especially in the western underdeveloped areas.

A nationwide exchange and sharing platform for teachers of Python programming language needs to be established, where excellent teachers can share their teaching materials and experience, lead and mentor other teachers in curriculum development. What they share will become a valuable asset to other teachers and greatly improve their teaching qualities. Students in the underdeveloped areas will be the ultimate beneficiaries, they can acquire a better educational experience which helps to improve their abilities as a result.

In addition to acting as a learning platform for new teachers and inexperienced teachers, the nationwide platform can also serve as a platform of exchange and cooperation. This platform enables teachers to find like-minded research partners to carry out teaching reform and research activities. Professional teachers from different universities can promote and inspire each other, brainstorm, apply collective wisdom, and produce more high-quality intellectual achievements together.

As a platform used by teachers and students in universities across the country, this platform can also collect big data for analysis, providing better data support for teachers' teaching and scientific research reform activities.

2.2 Virtual Teaching and Research Laboratory

The basic teaching organization, which takes the teaching and research section as the main form, is the cornerstone of promoting the connotative development of higher education in China [6]. The teaching and research laboratory in colleges and universities has gone through four basic stages: initial stage, finalizing stage, restoration and transformation stage, and imaginary stage [7]. The new economic development, which is characterized by new technology, new industry, new business form and new model, requires higher education to realize all-round innovation from concept, content, standard and method [8], including the forms of teaching organizations.

The Ministry of Education issued an announcement on the first batch of virtual teaching and research laboratories construction pilot (Letter of the Office of Education and High Education, no. 2, 2022) [9]. According to the announcement, 439 virtual teaching and research laboratories have been approved to pilot construction, and Python advanced computing virtual teaching and research laboratory is among them.

There have been some practice in virtual laboratories, but some of them just simply copy the physical teaching and research sections to the virtual community [10], some carry out cross integration of traditional entity teaching and research departments just in a limited number of cooperative universities [11, 12], some take the form of teaching organization facing students directly, such as platforms serving for multi-university joint talent cultivation [13]. Compared to these laboratory forms, the virtual teaching and research laboratories have more connotation.

Relying on modern information technology, the virtual teaching and research laboratories program aims at exploring the modes of constructing a new fundamental teaching organization, building a community of teachers, fostering a quality culture, Guiding teachers to return to teaching, love teaching, research teaching, improve teaching ability, providing strong support for the high-quality development of higher education.

The construction tasks of the virtual teaching and research laboratories program include:

- Innovate teaching and research forms: Make full use of information technology, explore efficient, convenient, diversified, online and offline blending teaching and research modes which can break through time and space restrictions, and form a new idea, new method and new paradigm for the construction and management of grassroots teaching organization.
- Strengthen teaching research: Guide teachers to strengthen the research and exploration of professional construction, curriculum construction, teaching content, teaching methods, teaching means, teaching evaluation and other aspects, improve the awareness of teaching research, condense and promote research achievements.
- Build high-quality resources together: Virtual teaching and research laboratory members, on the basis of full exchange, cooperate to build talent training programs, syllabus, knowledge maps, teaching videos, electronic courseware, exercises, teaching

cases, experimental projects, practical training projects, data sets and other resources, form a high-quality and shared teaching resource library.

- Carry out teacher training: Carry out regular teacher training, give full play to the demonstration and leading role of national teaching teams and first-class courses of famous teachers, promote mature and effective talent training models and curriculum implementation plans, and promote the teaching development of front-line teachers.

The construction target and tasks of the virtual teaching and research laboratories program are highly compatible with the problems and platform requirements of the Python programming language course. As one of the first batch of virtual laboratories, we have seen the development opportunity and direction of the course from the construction tasks of the virtual laboratories.

3 Construct Scheme of Python Advanced Computing Virtual Teaching and Research Laboratory

3.1 Membership and Organizational Structure

The members of Python advanced computing virtual teaching and research laboratory are mainly from "Python Language Working Group" of China University Computer MOOC (CMOOC) established in January 2016, the majority of which are Python course teachers in universities across China. According to a preliminary investigation, about 1000 teachers are planning to participate in this virtual teaching and research laboratory, covering more than 500 colleges and universities, including more than 30 in western China. There are also members who are representatives of enterprises that have substantial cooperation with Beijing Institute of Technology in the field of industry-education integration and collaborative education, including Huawei, Microsoft, Xilinx, Higher Education Press, Green Alliance, etc. All members can join and withdraw from the virtual teaching and research laboratory voluntarily.

The teaching and research laboratory adopts flat management mode. A laboratory management office is set up in Beijing Institute of Technology, responsible for the daily operation, maintenance and operation of the work group, drafting and formulating the annual plan, summarizing the annual work, etc. All members can directly participate in the teaching and research activities of the laboratory. Members from the same area can also set up a regional office to process area affairs. The overall organizational structure is shown in Fig. 1.

According to the development goals and tasks of the virtual laboratory, five groups are set up: curriculum group, new course group, teaching and research Group, platform group and teachers group. The curriculum group is responsible for the construction and sharing of the existing curriculum content and new curriculum resources. The new course group is responsible for the course application, development and resource construction of new courses. The teaching and research group is responsible for education and teaching research, teaching model exploration, academic exchange organization, integration of industry and education; The teachers group is responsible for training young teachers, improving teachers' ability, teaching evaluation and competition; The platform group is

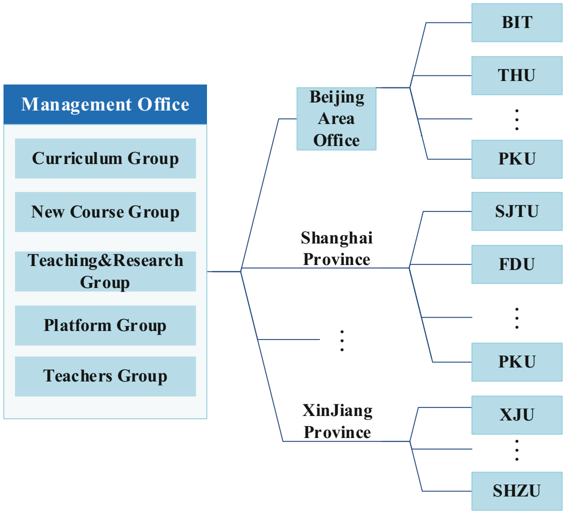

Fig. 1. Organizational Structure

responsible for the formulation of management rules and regulations and the maintenance of the digital platform.

3.2 Course System

The mission of Python advanced computing virtual teaching and research laboratory is to promote the development and reform of public courses in "advanced computing". The laboratory takes advanced computing as its teaching orientation, carries out the reform of a series of advanced computing public courses, including Python Programming Language, Data Analysis, Big Data Processing, Artificial Intelligence Literacy, Artificial Intelligence Programming, Artificial Intelligence Application, Network and Information Security, etc.

At the foundation period of the virtual laboratory, three curriculums are chosen to be the first batch of courses to be constructed, including "Python Language Programming", "Python Data Analysis" and "Python Artificial Intelligence Programming". All the three curriculums have already been running in Beijing Institute of Technology for several years and have accumulated abundant experience. With the three curriculums, the first steps of the advanced computing system path of "programming - Data Analysis - Artificial intelligence Development" have been constructed.

The overall course system of the virtual laboratory is shown in Fig. 2.

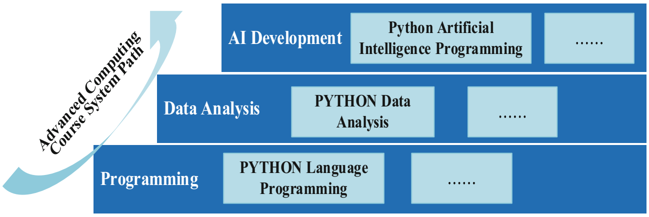

Fig. 2. Course System

3.3 Construction Scheme

The main tasks of Python advanced computing virtual teaching and research laboratory include basic platform construction, teaching system construction, education and teaching research, and teaching reform activities, etc. The purpose of the construction is to realize resource sharing, teachers' mutual assistance, and material co-construction, improve teachers' abilities and benefit students as a result.

The main tasks of Python advanced computing virtual teaching and research laboratory include basic platform construction, teachers exchange activities, resource library construction, education and teaching research, and practical achievements promotion. The overall construction scheme is shown in Fig. 3.

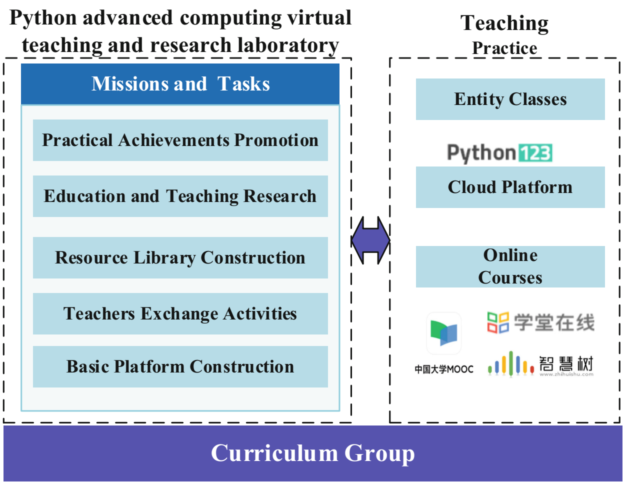

Fig. 3. Construction Scheme

Each construction task has its characteristic contents and products, as is shown in Table 1.

All the construction tasks are based on a basic national open platform, the development of which is also one construction task of the laboratory. Basic platform construction means mainly the development of the platform, which can provide management functions for the laboratory. For example, the platform can support membership management,

Table 1. Contents and products of each task

Task	Content and Products
Basic Platform Construction	Platform Development, Membership Management, Resource Display & Download, Activity Releasement, etc.
Teachers Exchange Activities	Teachers Training, Discussion, Teaching Evaluation & Competition, Project co-construction
Resource Library Construction	Syllabus, teaching video, electronic courseware, exercises, teaching cases, experimental projects, knowledge map, data sets
Education and Teaching Research	The educational reform paper The educational reform Practice
Practical Achievements Promotion	Promotion of new teaching concept, teaching methods, teaching modes and evaluation model, high-quality MOOC

resource display, document upload & download, activity releasement, etc. The platform is developed and managed by the laboratory management office. Members can register on the platform to participate in the construction of the teaching and research laboratory.

The development of the platform is based on Ali's DingTalk, and can provide technical support for laboratory's information dissemination, communication and document management.

Teachers exchange activities construction releases exchange activities initiated by the laboratory, such as teaching training, teaching communication, and discussion. The laboratory can also release some teaching research project and solicit participants who are interested.

Resource library construction can collect and organize diversified Python course resources, including talent training program, syllabus, teaching video, electronic courseware, exercises, teaching cases, experimental projects, knowledge map, and data sets. The resource library can be shared by and provide support for all the Python course teachers and greatly improve the course quality, especially in the western underdeveloped areas.

Education and teaching research construction can express excellent achievements of teachers' teaching research, such as papers. Teachers can also carry out teaching research cooperation in groups with the help of the platform and explore new teaching methods and teaching means.

Practical achievements promotion construction introduces new teaching concept, teaching methods, teaching modes, evaluation models, and the means of how to put them into reality. For example, a high-quality MOOC course can serve as the material of a flipped classroom.

As is shown in Fig. 3, teachers of the curriculum group can take advantage of the products and achievements of the construction procedure, put them into their teaching practice, including entity classes, cloud experimental platforms such as Python123, online courses on platforms such as MOOC. By utilizing the high quality resources on the virtual laboratory platform, teachers can put the innovative concept and modes into reality. During their courses, teachers can collect teaching data, for example, students' scores or feedbacks, which can be used as the basic platform's input to produce better achievements.

3.4 Benefit for Teachers and Students

The construction of new engineering is a timely response of higher education to the requirements of talent training, and cross-integration & cross-field training has become the inevitable choice of new engineering talent training mode [14]. The construction of Python advanced computing virtual teaching and research laboratory is an important reform and innovation of new engineering education in the field of advanced computing. Both teachers and students can benefit greatly from the construction of the virtual laboratory, as is shown in Fig. 4 and Fig. 5.

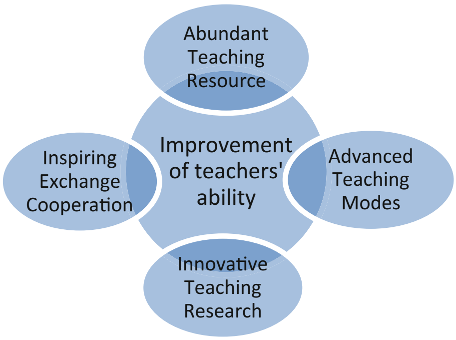

Fig. 4. Benefit for teachers

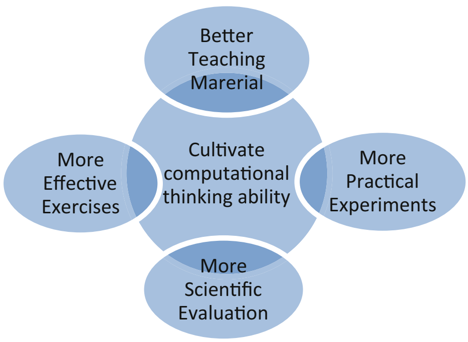

Fig. 5. Benefit for students

4 Problems to Be Solved

In the construction scheme of Python advanced computing virtual teaching and research laboratory, there are still some problems to be solved:

Firstly, how to fully protect the intellectual property rights of content providers in communication and sharing activities of the laboratory is still questionable.

Secondly, incentive needs to be developed to motivate enthusiasm of members.

Thirdly, how to promote demonstrative results of teachers' teaching and research, put teachers' advanced ideas and achievements in educational reform into practice is still an urgent problem to be solved.

5 Conclusion

With the continuous advancement of the pilot work of the virtual teaching and research laboratories, colleges and universities teachers will continue to deepen the exploration of the teaching organizations, promote the collaborative teaching and research, improve the quality of curriculum construction, promote the cross integration of disciplines, and promote the formation of new teaching paradigms and new mechanisms [15].

Though there are still some problems to be solved, it is hoped that Python advanced computing virtual teaching and research laboratory can break through the time and space constraints, combine online and offline models, bring an effective and diversified teaching and research modes for Python teachers across the country, play an important role in the equalization of education nationwide and the improvement of the overall teaching quality of Python advanced computing curriculums.

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Design of Teaching Model for Intuitive Imagination Development Supported by NetPad

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Abstract. As one of the core literacies in mathematics, intuitive imagination is essential in learning geometry in middle school. Recently, BOPPPS, which is a teaching model that featured clear objectives, has gradually become an effective course design model for cultivating students' intuitive imagination. Meanwhile, NetPad is a browser-based dynamic mathematical software that supports online mathematical experiments and dynamically displays geometric changes. In this paper, we propose a model called N-BOPPPS, which combines advantages of the BOPPPS teaching model and NetPad, aiming at developing students' intuitive imagination. This model consists of six procedures supported by NetPad, i.e., bridge-in, objective, pre-assessment, participatory learning, post-assessment, and summary. It supports classroom instructions such as the inquiry-based model and student-engaged model. Besides, it encourages students to carry out experimental investigations and innovative practice during the learning process, and then their intuitive imagination is improved. At last, teaching practice is conducted under the guidance of N-BOPPPS and the effectiveness of this model is verified.

Keywords: Intuitive imagination · NetPad · Teaching models

1 Introduction

In June 2020, the Ministry of Education promulgated the General High School Mathematics Curriculum Standards (2017 edition revised in 2020), which for the first time condensed and proposed the six core literacies of mathematical abstraction, intuitive imagination, mathematical modeling, logical reasoning, mathematical operations, and data analysis in mathematics [1]. In particular, intuitive imagination is quite helpful for exercising the mathematical mind. It can facilitate the composition of the abstract mind and transform it into a figurative mind in the process of mathematical geometry problem-solving. The inclusion of intuitive imagination in core literacy shows its significance of it in the development of students' learning and abilities.

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In the era of continuous development of science and technology, to ensure that we can effectively guide students to develop their core literacy, we must introduce new technologies and update our teaching sessions [2]. We could apply information technology to create an information-based environment to promote students' core literacy. Therefore, using information technology helps better develop students' intuitive imagination. NetPad is an online dynamic mathematical geometry software that uses mathematical logic, and graphical geometric constraint construction to draw graphs and create interactive digital resources. Furthermore, NetPad distinguishes itself from other dynamic geometry systems by being an open, internet-based, sharing-oriented intelligent system [3]. By integrating NetPad in class, we can achieve the integration of information technology and the subject.

At present, there are still some common problems in developing intuitive imagination in our mathematics education. For example, teachers are not proficient in using mathematical models in the classroom to develop students' problem-solving skills with graphs and failed to effectively guide students to think outside the box to let them try to use multiple graph drawing methods to solve the problem; the teacher; educators failed to utilize targeted IT software in the classroom, such incorporating dynamic geometry system (DGS) to assist in developing intuitive imagination to experience rich visuals, and teaching students to learn to use DGS in mathematical problem-solving [4, 5]. To overcome the above problems, educators should explore efficient teaching modes to cultivate students' intuitive imagination and create a lively atmosphere in the classroom to attract students to participate in learning. In addition, the BOPPPS teaching model has an effective teaching structure, which is a model that uses six instructional sessions such as effective introduction, timely assessment, and participatory learning, and it enhances teacher-student interaction and emphasizes student participation. In recent years, the BOPPPS model has been gradually introduced and practiced by scholars in China, with its practices showing that the model is an effective teaching model that can completely reflect the main position of students in the classroom, pay attention to the cultivation of students' thinking, and help teachers improve their effectiveness of teaching [6].

To sum up, based on the combination of the BOPPPS and NetPad, this paper proposes a teaching model called N-BOPPPS and its teaching practice that verified the effectiveness of N-BOPPPS. In Sect. 2, a review of the value of intuitive imagination and its concrete manifestation in math will be described. Also, the introduction of the BOPPPS model and the characteristics of the NetPad will be introduced. In Sect. 3, the N-BOPPPS teaching models will be proposed and introduced in detail. In Sect. 4, the process of teaching will be designed and practiced guided by the N-BOPPPS teaching model. In Sect. 5, we will conduct a summary analysis of the effectiveness of the practice.

2 Related Work

2.1 The Definition and Value of Intuitive Imagination

To understand intuitive imagination, we need to first understand geometric intuition and spatial imagination separately, for these two parts are pointed out by the New Curriculum as the factors that make up intuitive imagination. The definition of intuitive imagination in the New Curriculum Geometric intuition is the literacy of using geometric figures to analyze and solve mathematical problems, it can use simple graphs to represent the abstract concepts in mathematical problems or ideas to solve problems, and achieve the idea of "visualization" effect. According to the research of Tang P., geometric intuition has the advantage of visualization and simplicity, which can facilitate mathematical problem-solving. As for the performance of spatial imagination, by using the existence of objects in a certain space and their characteristics, positions, and other properties, we can imagine in our minds what already exists or create things that do not exist [7]. It can be understood as a dynamic graphical transformation process, such as the transformation and matching of relationships between geometry and three views and expansion diagrams. Moreover, the relationship between geometric intuition and spatial imagination is inseparable and interrelated. Geometric intuition is a process belonging to human cognitive activity, while spatial imagination is a method in this procedure, and the two have an interactive relationship in human cognitive activity [8].

As educators cultivate students' intuitive imagination, they need to focus on both geometric intuition and spatial imagination learning. Therefore, educators need to develop students' ability to use graphs to describe, understand, explore and solve mathematical problems, promote their learning to make connections between numbers and shapes, and help students build intuitive models of mathematical problems while building geometric intuition. Furthermore, In the process of developing students' spatial imagination skills, students are expected to formulate the cognition of three-dimensional space and master the symbols for describing spatial figures. Students should learn to match three-dimensional shapes with flat graphs and build the ability to disassemble and combine three-dimensional shapes, and finally provide new directions for problem-solving.

2.2 BOPPPS Model

The BOPPPS teaching model is the main teacher training model adopted by the Canadian ISW program, which is highly operable and has clear teaching objectives, and is gradually being developed in China, profoundly affecting teachers and students [9]. Moreover, the BOPPPS teaching model divides teaching sessions into six modules: bridge-in, objective, pre-assessment, participatory learning, post-assessment, and summary (see Fig. 1).

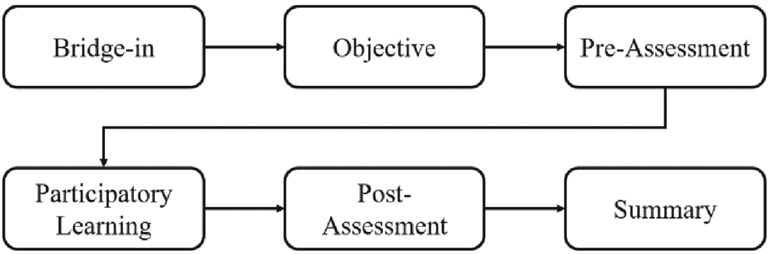


Fig. 1. BOPPPS model.

Bridge-in is the session that uses videos, questions or stories to attract students' attention, it can trigger students' curiosity and then introduce new content learning; Objectives make it clear to students that learning objectives or outcomes which the course needs to achieve; Pre-assessment is the session for teachers to know students' knowledge reserve and grasp their learning ability, so that they can adjust the content and progress of subsequent teaching sessions; Participatory learning reflects the concept of "student-centered" teaching and learning, which stimulates students' enthusiasm for learning by adopting active learning strategies and further deepens their understanding of the teaching content and finally achieve the learning objectives; Post-assessment is an important part of determining whether students have met expectations to see how well they have accomplished the learning objectives of the course; Summary can further enhance the students' impressions and consolidate the learning objectives by summarizing the knowledge points and the knowledge chain of this course.

Since the BOPPPS teaching model has been introduced to China for a relatively short period, there are fewer studies about its application to the cultivation of core literacy in mathematics [10]. However, by applying the BOPPPS model to the development of core literacy in other subjects, we can learn that this model has positive effects on developing students' core literacy compared with the traditional teaching model, and can be applied to the teaching of developing intuitive imagination skills.

2.3 NetPad

NetPad is a cross-platform Dynamic Geometry System with rich dynamic mathematical resources and powerful geometric drawing capabilities [11]. NetPad offers a 2D drawing area (Fig. 2) and a 3D drawing area (Fig. 3). It allows not only geometric drawing and symbolic computation but also automatic reasoning about geometric shapes, seamless integration with other systems, as well as providing a convenient platform for sharing and communication.

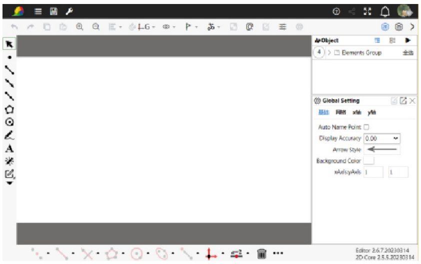


Fig. 2. 2D drawing area on NetPad.

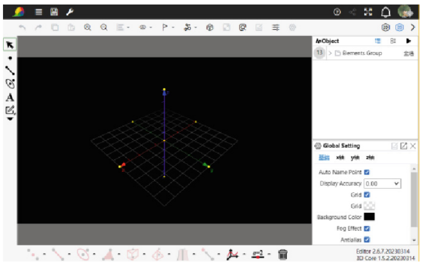


Fig. 3. 3D drawing area on NetPad

Many Chinese researchers have discussed the meaning and role of NetPad and given the advantages of NetPad in teaching mathematics. According to the research of Wang J.X., the picture preview method of the web board can provide teachers and students with accurate interactive educational resources quickly and easily [12]. What's more, based on the CCEMS-based evaluation model, it is effectively verified that the NetPad pays attention to user experience and that it can satisfy both teachers' and students' needs [13].

In the era of informatization in education, the advantages of NetPad such as the large user community and rich teaching resources provide alternative teaching tools and teaching materials of various types levels to promote the integration of information technology and courses. Thus, teachers can create contexts, set inspiring questions, and guide practice in teaching through NetPad. Moreover, students are also able to form a systematic knowledge system of mathematics with the support of NetPad, develop their problem-solving skills and IT operational skills, and finally improve core literacy.

3 N-BOPPPS Teaching Model

Based on the BOPPPS teaching model and NetPad, this paper proposes the N-BOPPPS teaching model. The model involves the entire teaching and learning activities, which would enhance students' creative awareness, problem-solving skills, and intuitive imagination (see Fig. 4).

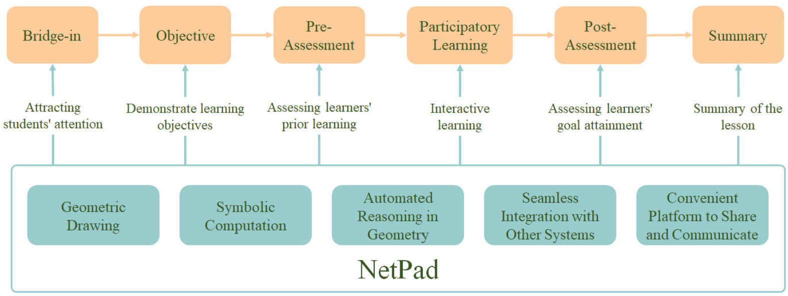


Fig. 4. N-BOPPPS teaching model.

Bridge-in: An orientation session before formal teaching. The teacher uses specialized NetPad cases to attract students' attention and raises questions to guide students' thinking as well as interact with them, gradually moving to the core part of the teaching. Furthermore, teachers can use what they have already learned in the last class to make organic connections with what they will be learning, which can be visually displayed through NetPad.

Objective: Setting learning objectives based on the requirements of intuitive imagination. The teacher sets the three-dimensional objectives (Fig. 5) of teaching with a clear understanding of the core knowledge of the class, the needs and the abilities of the students, and the requirements of each level based on intuitive imagination. Importantly, these objectives explicitly state the requirements and levels that should be achieved through learning in terms of knowledge and skills, process and methods, as well as emotions and values.

Pre-assessment: The session of understanding students' interests and prior knowledge. The teacher utilizes well-designed cases to assess learners' prior knowledge and graphic

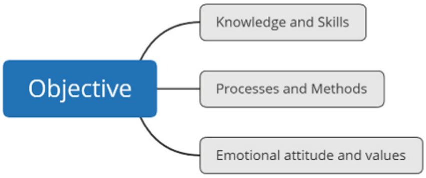


Fig. 5. Three-dimensional teaching objectives.

intuition and then guides the pace of the teaching process and subsequent arrangements. Through the interaction of information between teachers and students, teachers can understand students' interests and abilities to facilitate teaching and learning, while students can review previous knowledge points to lay the foundation of knowledge for the subsequent learning that takes place in class.

Participatory Learning: Teachers and students use NetPad to interactively learn the core content and enhance their intuitive imagination in the process. To reflect a student-centered position and motivate students, participatory learning is a core aspect of the N-BOPPPS model. The educator uses NetPad to create a simple and intuitive context, first showing the case and explaining the steps to guide students to actively participate in class. When most students have completed the basic drawing, the teacher gives students sufficient time to explore different solutions and encourages them to discuss and help each other in small groups to complete the work together and eventually lead them to achieve the objectives.

According to the combination of teaching theme and case, use the questioning method to develop students' thinking and lead them to reflect, then use NetPad to reproduce the process of solving the problem, so that students can deduce many things from one case. Students use the properties of graphs in class to explore mathematical patterns, discover the connections between graphs and quantities, and develop solutions to use graphs to solve problems.

Post-assessment: An assessment or test session to see if students have accomplished the learning objectives. The teacher checks students' knowledge understanding of the lesson by displaying some simple multiple-choice questions or creating problem situations and organizes students to conduct a comprehensive analysis to assess whether students' general quality and problem-solving skills have been improved. And then, the teacher collects students' work and allows them to present and share concepts of their work so that they could have a clear understanding and integration of what they have learned.

Summary: A conclusion of the lesson to help students deepen their knowledge. The teacher makes comments on students' work and praises their efforts as well as their learning achievements timely so that students can gain a sense of self-efficacy and accomplishment. Finally, the teacher uses NetPad to display a summary of knowledge points, organize and review the lecture content, provide timely feedback on the lesson, and guide students to further consolidate the learning objectives.

4 Teaching Practice Based on N-BOPPPS

Based on the guidance of the N-BOPPPS model and the knowledge related to square roots, this section implements the case of "$\sqrt{n}$ on the number axis" on NetPad and carries out instructional practice (see Fig. 6).

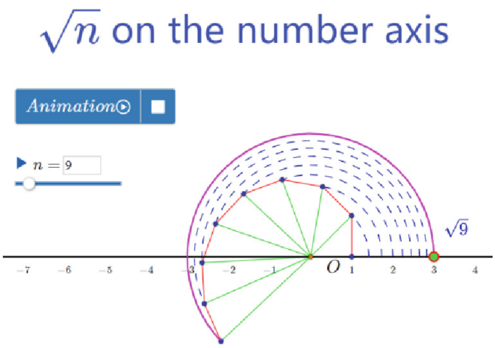


Fig. 6. $\sqrt{n}$ on the number axis.

Bridge-in: Since students have already mastered the position of simple rational numbers on the axis, teachers design problems that will be displayed in NetPad. The problem is taken as the core content that needs to be solved in this lesson so that students can think about the problem before the class starts, stimulate their interest in learning, establish the basic concept of graphical and quantitative relationships, and complete the thinking training of graphical description and induction.

- Question: We all know that there is a "one-to-one" relationship between the points and the numbers on the number axis, and know how to draw the numbers 1, 2, or −2, −4 on it. However, do you know how to quickly find the point of $\sqrt{2}$ on the number axis with NetPad? What about $\sqrt{17}$?

Objective: Before entering the formal lesson, use 2 or 3 min to communicate to students the learning objectives of the lesson. Then, allow students to begin by broadly framing what they will learn in class and developing an overall understanding. Ensure that students are clear about the purpose of the class.

The three-dimensional objectives are the following:

Knowledge and Skills: Can accurately describe the relationship between the position of $\sqrt{n}$ on the number axis and the characteristics of its distribution; can try to inductively verify the mathematical principle behind the position of $\sqrt{n}$ on the number axis as the Pythagorean Theorem; can be able to imitate display cases to produce graphs of the position of $\sqrt[3]{n}$ or n^2 on the number axis.

Processes and Methods: Master the methods of constructing visual displays of geometric figures and solving problems in mathematical problem situations; Experience the process of exploring questions and developing your own methods of learning and solving geometric problems.

Emotional attitude and values: Experience the rules of motion when the relationship between graphs and quantities changes through cases; through the spiral line shown in the case study, perceive the beauty of mathematical figures, which in turn stimulates the interest in learning math.

Pre-assessment: Using questions to guide students to test their knowledge and visual level of graphics before class, the teacher understands students' interests and motivation according to their answers and then adjusts the teaching progress in time, which helps to achieve the classroom teaching objectives through the interaction between teachers and students.

- Question: What are the elements of the number axis? (Students make a diagram to describe or answer directly)
- Question: What are the meaning and properties of square roots? How do you distinguish square roots from arithmetic square roots? (Students summarize the characteristics)
- Question: Where are the common square root numbers, e.g., $\sqrt{16}$, $\sqrt{49}$? located on the number axis? (Students quickly point to the corresponding positions or describe them orally.

Participatory Learning: Use NetPad to guide students to join the learning process, which reflects the concept of "student-centered" education. The use of problem-driven, cooperative learning and independent student inquiry in the teaching is very motivating for students.

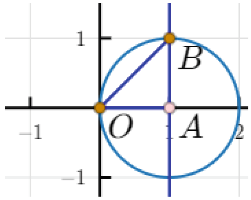
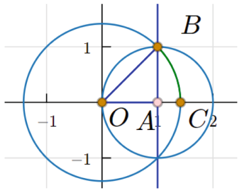
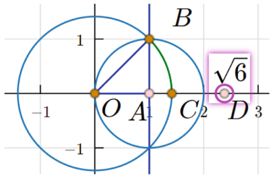
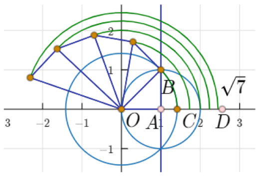
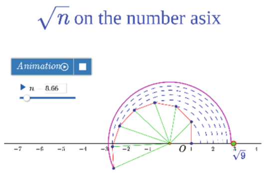
Perform the steps of the case on the drawing board, and combine them with questions to attract students' attention, such as "What is the next missing step", "What kind of graphical effect can be obtained from this step", "Why should we do this", etc. The specific steps are shown in Table 1.

After showing the steps of the case, students are guided to imitate the operation and reproduce the case. If students encounter difficulties, they are encouraged to communicate and discuss with their partners and then complete the work together. For students who are quick to complete their work, teachers can intentionally guide students to consider the patterns of quantity and graphical change or to use NetPad to create, such as an exploration of the location of $\sqrt[3]{n}$ or n^2 on the number axis.

Post-assessment: After completing the class, the teacher set up test questions that correspond to the learning objectives and target different dimensions to test the learning effect such as basic concepts, case design, and mathematical principles.

- Question: Which characteristic of the distribution of the position of $\sqrt{n}$ on the number axis does the case reveal? (Students answer)
- Question: What is the mathematical principle behind the distribution of $\sqrt{n}$ on the number axis? (Students answer and give a simple proof)
- Referring to this case, what should $\sqrt[3]{n}$ or n^2 look like on the number axis? (Students give a general description and work on the case after class)

Table 1. Steps of "$\sqrt{n}$ on the number axis".

Step	Result
Step 1: Make line segment AB and BO (see Fig. 6) a: Make the point A (1,0) and make a vertical line from the point A to the origin O. Make a circle of radius 1 with point A as the center, make the intersection of the circle and the vertical line B, make the line segment AB and the line segment BO;	 **Fig. 7.** The effect of step 1.
Step 2: Make point C (see Fig. 7) a: Take the point O as the center and the line BO as the radius to make a circle O, make the intersection of the circle O and the x-axis C; b: Introduce the variable n, make the arc BC with the point D (sqrt(n),0), "x-drag" for n.	 **Fig. 8.** The effect of step 2.
Step 3: Additional graphing (see Fig. 8) a: Parameter animation for variable n. Then, make free text and set the text property to "$$sqrt($$bl{n,0})$$"; b: Merge free text and point D. Use the [Attach/Separate/Merge] tool to merge free text and point D, then hide the text.	 **Fig. 9.** The effect of step 3.
Step 4: Iterative mapping (see Fig. 9) a: Iterate the graph. Set "original image" to point A, "reflection" to point B, "iteration depth" to n-2, "iterated objects" to point B, line AB, line OB, and arc BOC.	 **Fig. 10.** The effect of step 4.
Step 4: Beautify the graphics (see Fig. 10) a: hide the redundant elements (circle O, circle A, and the vertical line), and finally set the graphic color according to your preference.	 **Fig. 11.** The effect of step 5.

Summary: After evaluating and encouraging students' work, the teacher summarizes the relevant knowledge points. In this class, students will explore the problem of "$\sqrt{n}$ on the number axis" through a case demonstration on NetPad. Students experience the relationship between graphs and quantities while participating and creating cases in NetPad, then learn how to use the relationship between graphs and graphs, as well as between graphs and quantities to solve problems. Students further facilitate the formation of intuitive models of problem-solving by visualizing visual and imaginative stimuli through graphics.

5 Conclusion

Based on the BOPPPS teaching model, this paper proposes the N-BOPPPS, which aims at developing students' intuitive imagination, and finally carries out teaching practice supported by NetPad. During the practice, the teacher guided students to cooperate and explore not only to complete the case but also to verify the mathematical principles behind the case to summarize the distribution of $\sqrt{n}$ on the number axis.

With the N-BOPPPS teaching model, teachers can organize situational and structured knowledge in teaching sessions, while students learn to use the number axis to determine the positions of rational numbers, gain an initial understanding of spirals, and understand the relationships between different number systems with the help of models and knowledge organization. Students master the solution of the relationship between graphs and graphs or between graphs and quantities by working with group members. Finally, students will continue to improve their level of intuitive imagination skills, truly discover the role and significance of graphical intuition in learning, and develop the mindset of using geometric intuition to solve problems.

However, there are still some improvements needed in the teaching practice based on the N-BOPPPS model. In future research, we will pay more attention to the collection and analysis of experimental data, and use the data to support the detailed improvement of the N-BOPPPS model; we will combine effective assessment methods to test students' intuitive imagination level; we will conduct more N-BOPPPS-based teaching practices for different chapters of mathematic. In summary, the N-BOPPPS teaching model has a positive effect on the development of students' intuitive imagination literacy. More teaching practices should be conducted in the future to continuously improve N-BOPPPS and promote the practice on a large scale to help cultivate students' intuitive imagination effectively.

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Research on NetPad Teaching Mode Based on ARCS Motivational Model

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Abstract. Stimulating and maintaining students' learning motivation is the key to fully mobilizing the enthusiasm of students' active participation and realizing the unity of students' learning and teachers' teaching. The ARCS motivational model is an instructional design model proposed by Professor Keller that focuses on motivating and sustaining students' learning motivation. Additionally, NetPad is a web-based dynamic mathematics software with powerful functions and user-friendly interface, it can be organically integrated with teaching, enrich the teaching style, and strengthen students' learning motivation. In this paper, we propose the NetPad motivational teaching mode based on the ARCS model and NetPad. This mode consists of four procedures: interesting cases introduction, detailed cases explanation, group inquiry, and mutual evaluation and sharing. Each procedure is progressive and complementary, reflecting the hierarchy of motivational teaching from shallow to deep and the synergy of motivation stimulating and maintaining. The teaching practice under the guidance of this mode has verified its effectiveness.

Keywords: ARCS Model · NetPad · Learning Motivation

1 Introduction

The deep integration of information technology and subject teaching is the key concern and development in the era of education informationization 2.0. COVID-19 has accelerated the process of applying the Internet for education in China, and put forward higher requirements for the integration [1].

Dynamic geometry software can promote the deep integration of information technology and education [2]. NetPad is one of the dynamic geometry software under the mobile Internet environment, it was officially released in 2016 and gradually entered the mathematics classroom in primary and secondary schools. However, such an outstanding subject tool has not been applied widely yet, and its relevant study is not enough. To make

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the problem clear, we research papers and eventually find the key element i.e., learning motivation. Learning motivation plays a key role in technology-integrated instruction and it can significantly affect students' studies [3]. Therefore, attention should be paid to motivating students in NetPad teaching.

Karakis found that the ARCS model applied in mathematics courses can positively influence students' academic achievement and learning attitudes [4]; Li and Keller showed that the ARCS model has a positive impact on students' learning motivation in computer-based instruction and the IT-supported environment is also the preferred learning environment for the model [5]. Therefore, the article attaches importance to stimulating and maintaining students' learning motivation in the teaching process and proposes a NetPad motivational teaching mode based on ARCS model. Under the guidance of this mode, the teaching practice is carried out, and the students' classroom performance is positive, which verifies that this mode can promote students' learning motivation.

The structure of this article is as follows. Section 2 introduces the connotation of learning motivation and the ARCS model as well as elaborates the connotation and characteristics of NetPad. In Sect. 3, we propose a NetPad motivational teaching mode based on ARCS motivational model. Section 4 is the teaching practice, we have applied the NetPad motivational teaching mode to carry out 10 lessons for junior high school students, and select one of the lessons to specifically elaborate the teaching process. Section 5 concludes the article and provides future research directions.

2 Related Work

2.1 Introduction to the Connotation of Learning Motivation and the ARCS Model

Motivation is the internal state that directly drives human activities to meet certain needs, and is the direct cause and internal motivation for people to learn, which can stimulate, direct and maintain learning behavior, which is the main reason for students' participation in the classroom.

Motivation in mathematics is a conscious behavioral tendency caused by a certain need related to mathematics learning, which motivates and pushes students to behave toward learning goals. The strength of motivation affects individual learning emotion, classroom participation behavior and other related mental activities, and positive learning motivation is conducive to individual effective participation and deep learning [6].

The ARCS model was proposed by Professor Keller in the 1880s to stimulate and maintain students' learning motivation. Professor Keller argues that learning motivation is not unpredictable and uncontrollable; on the contrary, research shows that by integrating ARCS motivational model strategies in the curriculum, teachers can systematically and efficiently stimulate students' learning motivation and maintain their motivation at a relatively high level [5]. Learning motivation plays a key role in students' learning of the subject knowledge and achieving their learning goals, which should be incorporated into the teaching design of NetPad. The ARCS motivational model contains four elements: A-Attention, R-Relevance, C-Confidence, and S-Satisfaction [7]. First, in order to motivate students, teachers and teaching content should attract and maintain students' attention; second, the learning content should meet learners' needs and should be relevant; moreover, the course should allow students to have successful experiences and build self-confidence through task setting; Finally, when students are satisfied with their achievements and their efforts are consistent with expectations, their motivation to learn can be sustained [8].

2.2 Connotation and Characteristics of NetPad

The development of the NetPad uses dynamic geometry, intelligent reasoning, symbolic operation, and network interaction technology, is an "Internet plus Dynamic Mathematics" learning platform, with the characteristics of dynamic visualization, and has rich online resources [9]. Meanwhile, the NetPad is a powerful subject tool, which can be used as a learning garden for teachers and students to explore mathematics problems. As follows:

Dynamic Visualization. NetPad expresses abstract mathematical knowledge in an intuitive form, realizes dynamic change, and brings visual dynamic demonstration process for teachers and students; using NetPad can effectively build a bridge between students' cognition and abstract mathematical symbols, thereby reducing students' cognitive difficulty, promoting understanding, stimulating learning interest and learning motivation.

Internet plus Dynamic Mathematics. NetPad is fully adapted to the existing Internet environment, and can be simply registered on the web page; NetPad is deeply rooted in the mathematical discipline, which can realize the functions of "writing, drawing, measuring, transforming, editing, acting, reasoning, calculating", not only as an environment for students' daily learning and experimental exploration but also as a platform for teachers' lesson preparation and progressive teaching.

Rich Online Resources. All the resources created by the NetPad users are gathered in the NetPad cloud so that users can search for the resources they need on the website. During the learning and application process, students can appreciate the works of others, thus generating their own creative inspiration, and change from knowledge learners to content creators, which is also conducive to the acquisition of satisfaction and the maintenance of learning motivation.

3 NetPad Motivational Teaching Mode Based on ARCS Motivational Model

3.1 ARCS Motivational Strategy Analysis and Application

This part analyzes four types of strategies for the ARCS motivational model proposed by Keller, namely attention strategies, relevance strategies, confidence strategies, and satisfaction strategies [10, 11]. To adapt to the teaching process of NetPad, this article combines the characteristics of NetPad and proposes action in NetPad instruction strategies. As the figure shown in Fig. 1.

Category	Subcategory	Action in NetPad Instruction
Attention Strategies	Perceptual arousal Inquiry arousal Variability	Introduce surprising cases; Arrange the question inquiry process; Adopt a variety of teaching methods.
Relevance Strategies	Goal orientation Motive matching Familiarity	Inform the students of the main contents and objectives; Set challenging questions and arrange for group cooperation; Select interesting, lifestyle cases.
Confidence Strategies	Learning requirements Success opportunities Personal control	Raise the course learning requirements; Provide successful opportunities frequently; Give students certain autonomy.
Satisfaction Strategies	Intrinsic reinforcement Extrinsic rewards Equity	Provide opportunities to apply new knowledge; Provide verbal praises and material rewards; The evaluation criteria are open, transparent, and equal to all students.

Fig. 1. Motivational strategies and action in NetPad instruction.

Attention Strategies. This type of strategy focuses on responding to students' demand for stimulation and arousing students' curiosity to explore knowledge, including perceptual arousal, inquiry arousal, and variability strategies. Attracting attention is not difficult, the key is how to maintain students' attention [10].

For perceptual arousal, teachers can attract students' curiosity and attention by introducing a surprising piece of information related to course content, so that students can be engaged in the study quickly; For inquiry arousal, question-seeking activities should be arranged during the process of instruction, in order to further stimulate students' curiosity. Meanwhile, the rich online resources of NetPad can provide help and support for students' exploration; For the diversity strategy, teachers are supposed to adopt various teaching methods combined, bring freshness to the classroom, and maintain students' attention.

Relevance Strategies. This type of strategy focuses on meeting students' perceived need, so that students can form positive learning attitudes, including goal orientation, motivation matching and familiarity strategies [10].

For goal orientation, teachers should briefly introduce the main contents and objectives of the course to students before entering into the detailed case study, so that students can understand the course structure. In the process of teaching, teachers are suggested to set challenging questions and arrange group inquiry activities, so that students who are eager to have a sense of belonging or eager to be challenged can both realize the motivation matching. Mathematics is a subject that frustrates many students, and the difficult and abstract theoretical knowledge will make students feel resistant, while the dynamic visualization of NetPad can solve this problem well. At the same time, teachers should select interesting and lifestyle cases for the course, so that students can experience a sense of familiarity and thus maintain their learning motivation.

Confidence Strategies. The focus of this type of strategy is to enable students to hold positive expectations for success and build self-confidence in the learning process, thereby sustaining motivation. Strategies encompass learning requirements, opportunities for success, and personal control [10].

For the learning requirements' strategies, teachers should present the learning requirements in the classroom; during the instruction, teachers should design teaching contents step by step and set progressively difficult problems according to the teaching contents, and reasonably arrange the instructional pacing so that students can achieve success and build self-confidence in the process of continuously solving problems and mastering new knowledge; For personal control strategies, teachers should give students a certain degree of autonomy in the classroom, so that they can set their own pace and regulate their learning behaviors, and at the same time make students realize that they can achieve a certain degree of success by making efforts.

Satisfaction Strategies. Satisfaction is a category emphasizing strategies that help learners feel positive about their achievement, including intrinsic reinforcement, extrinsic rewards and equity [10].

For internal reinforcement strategies, teachers should provide opportunities to apply new knowledge so that students can learn and feel rewarded, and provide feedback to reinforce positive feelings about effort and achievement; for external reward strategies, teachers can provide verbal praises and material rewards to reinforce the satisfaction and sense of achievement that success brings to students; for equity strategies, teachers must ensure that students' work is evaluated fairly, and evaluation criteria are open, transparent, and equal to all students.

3.2 NetPad Motivational Teaching Mode

Based on ARCS model, combined the characteristics of NetPad, we propose the NetPad motivational teaching mode. With the integration of ARCS motivational strategies, the mode encompasses four procedures: interesting cases introduction, detailed cases explanation, group inquiry, mutual evaluation and sharing. Each procedure mainly corresponds to one motivation element, as well as taking one or two other motivation elements into consideration. These four procedures are progressive and complementary, for the stimulation and maintenance of motivation is from shallow to deep. As the figure shown in Fig. 2.

Interesting Cases Introduction. Attracting students' attention is the first element of the ARCS model, and it is also a necessary prerequisite to stimulating students' learning motivation. This step focuses on attracting students' attention, as well as taking relevance element into consideration.

By introducing a classical math story or interesting math experiment related to the course content, students' attention can be attracted immediately. In demonstration and explanation, teachers should establish the connection between the interesting introduction and course content. Using the NetPad, teachers can easily set up the bridge between abstract mathematics theory and students' intuitive imagination, in order to stimulate

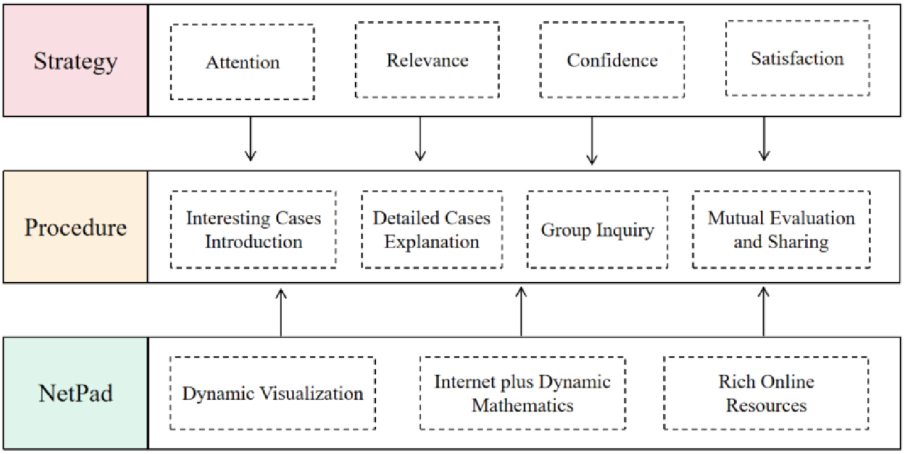


Fig. 2. NetPad motivational teaching mode.

students' curiosity and motivation, reduce the difficulty of students understanding new knowledge. At the same time, the selection of each instruction case serves the core knowledge points of the course and has a logical correlation with the subsequent cases.

Detailed Cases Explanation. This step focuses on creating successful experiences and building students' confidence, and also takes attention and relevance motivational elements into consideration.

After the introduction of interesting cases, teachers should raise the learning requirements, main contents, and objectives of this class, make sure that students hold a positive expectancy for learning, as well as stimulate students' motivation. Then, select both basic case and expanded case that serves the core knowledge points of the course. The difficulty of the case is incremental, and teachers should carry out the instruction step by step, in order to help students build confidence, and make them believe that they can master the course knowledge. The selected cases should be interesting and structurally correlated, to prevent students from feeling boring, irrelevant, and non-challenging. Moreover, the teaching pacing should be timely adjusted with the change in the classroom atmosphere, to maintain students' motivation. Also, teachers should keep track of students' mastery of new knowledge, and further explain the key points, difficulties, and error-prone details, to ensure that students can master the operation of NetPad, attain successful experiences, and build up confidence.

Group Inquiry. This step focuses on producing relevance, and also takes attention and satisfaction motivational elements into consideration.

In this step, a challenging lifestyle question is introduced for group inquiry. Students are asked to apply their knowledge in exploring the question in free groups and create their own works. With the support of NetPad, students can share rich online resources and then generate innovative inspiration. Moreover, students feel satisfied with themselves through the process of exploration and application, and have a sense of familiarity with the challenge and the cooperation of others.

Mutual Evaluation and Sharing. This step focuses on generating satisfaction, and also takes confidence motivational elements into consideration.

Each group is required to select one piece of work for display in class; the work owner is invited to introduce the creative inspiration and idea for other students to learn from. Finally, students are required to summarize their gains today and share in groups. This process can promote students' in-depth understanding of knowledge and tool application, help them generate satisfaction, and maintain their learning motivation at a high level.

4 Teaching Practice

Under the guidance of the mode, a series of NetPad teaching practices were carried out for junior high school students, and the practices contained three parts: graphic design, number-shape combination and iterative fractal, with a total of 10 lessons and 20 class hours. In the following, we select one lesson of the number-shape combination part to elaborate how the teaching process realize the mode.

4.1 Teaching Objectives

Through the widely spread story behind the Cartesian heart function, let the students feel the romance and charm of mathematics, and understand that mathematics exists in all aspects of life. To attract students' attention and stimulate students' motivation.

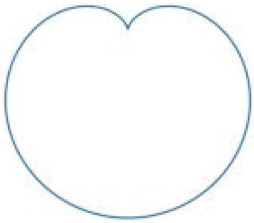
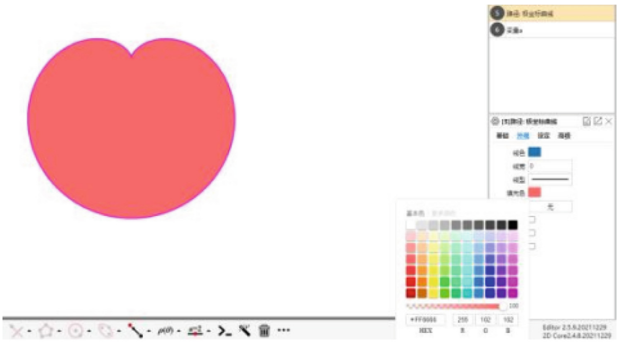
Through the drawing of the Cartesian heart function, make the students understand the meaning of the function, grasp the application of the function tools, and understand that function graphs connect mathematical equations and things in life. Through the drawing of the "Multi-Layer Heart" curve, make the students further understand the application of function, master the function tools, and master the drawing ideas and methods. To help students build up confidence and maintain students' motivation.

Through the exploration and inquiry in groups, cultivate students' exploring and innovating abilities, make them feel satisfied and familiar, then motivate them to further use NetPad in exploring mathematics problems. To help students generate satisfaction and maintain students' motivation.

4.2 Teaching Implementation

Interesting Cases Introduction. In this procedure, asked question 1(Q1) and then told the romantic love story behind Cartesian heart function; which led to the concept of coordinate system and function, established the connection with students' grasped knowledge. Q1 is shown below.

Table 1. Cartesian Heart Drawing Steps.

Steps to Make a Cartesian Heart
Step 1: Basic Graphing a. Use the "Function Figure toolset -> polar equation" to plot the function curve ρ = a * (1 - sin(thet)), set the "independent variable" 0 ≤ thet ≤ 2*pi, figure is shown below. 
Step 2: Interface Optimization a. Adjust the curve position. Select "Object Group -> Coordinate Origin" and move to the center of the canvas. b. Optimize the function curve. Select the curve and set it through the "Appearance" property dialog box, figure is shown below.
Steps to Make a Cartesian Heart
 c. Beautify the canvas, set the canvas color through the "Base" property dialog, set the polar grid through the "Grid" property dialog, figure is shown below. 

Q1: Have you ever heard of the Cartesian heart function?

Students had heard the story behind the Cartesian heart function in their math interest books; some active students raised their hands to express their understanding; and the class was highly participatory and active.

Detailed Cases Explanation. After the introduction of interesting cases, raised learning requirements, main contents and objectives of this class, then began the procedure with a base case - Cartesian Heart function, and then elaborated an extended case - Multi-Layer Heart, to help students grasp the procedure of graphing a function curve.

Base Case - Cartesian Heart Function. Introduced the function figure toolset and appearance attribute box needed in the basic case, explained the drawing process of the Cartesian heart function step by step, controlled the students' screen in the first demonstration, exited the full-screen control in the second demonstration, made sure that all the students can control their learning pacing, and made independent exploration and innovation after completing the heart function draw. The specific operation steps are shown in Table 1.

Extended Case - Multi-Layer Heart. Before getting to the next case, asked students question 2(Q2), Q2 is shown below.

Q2: Based on what you have learned, could you elaborate the steps of graphing the "Multi-Layer Heart"? The figure is shown in Fig. 3.

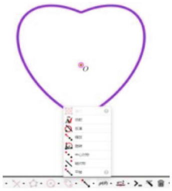
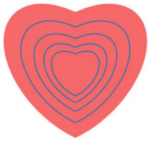
Fig. 3. Multi-Layer Heart.

Used the function figure toolset which was used in the basic case to explain the drawing process of "Multi-Layer Heart", controlled the students' screen in the second demonstration, some students could control their learning pacing and completed the "Multi-Layer Heart" after independent exploration. The specific operation steps are shown in Table 2.

Group Inquiry. Introduced question3 (Q3) and required students to apply their knowledge in exploring the question in free groups and created their own works. Q3 is shown below.

Q3: Could you find another way to graph the heart curves in NetPad? Are there any other function curves you can make that depict real things in our lives?

Table 2. “Multi-Layer Heart” Drawing Steps.

Steps to Make a "Multi-Layer Heart"
Step 1: Basic drawing
a. Use the "Function Figure toolset -> Polar Equation" to plot the function curve ρ = 15 / (17 - 16 * sin(thet) * abs(cos(thet))) ^ 0.5, set the "independent variable" pi / 2 - t ≤ thet ≤ pi / 2 + t, figure is shown below.

b. Use "Transform toolset -> Scale" to scale Figure 4 times, figure is shown below.

c. Use "Variables and Actions tool group -> Variables" to create variable a, set "Max" to 1, "Increment" to 0.1, "Current value" to 0.76.
d. Use "Variables and Actions tool group -> Animation" to create an animation effect, set "Type" to "Once", "Variables " is "t", "stop" is pi, "interval" is 20.
Step 2: Interface Optimization
a. Use "Show -> Hide Elements" to hide the variable slider for variable a and variable t.
b. Optimize the function curve. Select the curves from the outer layer to the inner layer, and set the color fill and transparency respectively, figure is shown below.


Students were able to complete innovative cases based on the operations they had learned, and group discussions and exchanges were lively.

Mutual Evaluation and Sharing. Each group was asked to select one piece of work for display in class; the work owner was invited to introduce the creative inspiration and idea for other students to learn from. Meanwhile, teachers gave verbal praises to the outstanding students and progressive students. Finally, students were asked to summarize what they have learned today, and share and communicate with other students. In the last of the ten classes, we awarded certificates of completion to all students who passed the attendance and prized to those who excelled in class.

5 Conclusion

This article aims to apply ARCS motivational model in the process of NetPad instruction, to stimulate students' interest in NetPad and learning motivation, ignite students' mathematics learning internal motivation, allow students to explore mathematics independently, cultivate students' ability to explore the thinking process of mathematics problems. We propose a NetPad motivational mode based on ARCS model and NetPad, and verify its effectiveness in the teaching practices.

However, the effectiveness of NetPad motivational teaching mode needs to be verified in more practices; and the mode lacks empirical analysis. In the subsequent work, conduct questionnaires and paper design tests for students' motivation level, analyze and explain student data before and after the teaching experiment, to further clarify the effect of experiment on students' motivation and achievement.

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Practice of "Two Learning and Two Education" Talents Cultivation Mode in Computer Innovation and Entrepreneurship Education

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Abstract. Under the background of "The New Engineering", the original computer educational concept has been unable to meet the needs of the great development of social informatization. This study tries to utilize the student-centered approach, puts forward a "Two Learning and Two Education" talents cultivation mode including Case-Based Learning, Project-Based Learning, Competition Inspire Education and Industry Cooperative Education, states its frame structure and connotation. After several years of teaching practice, the innovation and entrepreneurship education in our college has achieved a good result and produced a good social effect.

Keywords: talents cultivation mode · computer innovation and entrepreneurship education · Competition Inspire Education · Industry Cooperative Education

1 Introduction

In today's world, the fourth scientific and technological revolution, industrial revolution and educational revolution, characterized by intelligence and informationization, are speeding up the innovation pattern reshaping. Innovation has become the primary driving force leading national development and winning the initiative in international competition. The "four new" construction, which is new engineering, new medical science, new agricultural science and new liberal arts, has been strategically chose to cope with the challenges of scientific and technological revolution and international competition. Computer science, as the important pillar discipline for "four new" construction, has become an indispensable basic subject in 21st century, and computer talents cultivation mode needs more boldly explore its uniqueness, which is the role of blending other disciplines, also of facilitating youth innovative thinking development. Its ultimate goal is to cultivate computer innovation and entrepreneurship talents with strong comprehensive thinking ability.

We try to find a talents cultivation mode and new path which is suitable for the Chinese university students' characteristics and Wuhan University reality. At the same time, we also find the optimal solution to cope with a series of problems and challenges when pushing forward college students innovation and entrepreneurship education such as teaching concept renewal, program updates, new platform construction and the teaching staff structure optimization.

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2 "New Engineering" Educational Background

Society transformation inevitably leads to talents transformation. Under the country's demand for talents in the future, colleges have to become the leader and pioneer of delivering qualified key technological research personnel. On the other hand, the dependence on computer in today's world cannot be ignored. Therefore, as teachers of computer subject in college, we should explore practical course teaching method to adapt to the new environment with the growth thinking of transferring "what to teach" to "how to teach" [1]. But we cannot copy the foreign teaching mode, because China's national conditions, culture and characteristics of college students are different. Through analyzing the computer undergraduate practical courses status, the following bottleneck aspects are summed up.

It is not effective to carry out teaching in teams or project groups for university freshmen because of a large students amount in this major, and low adaptability of new students changing learning style from high school to university. In addition, there is higher teaching requirement for teachers based on different knowledge foundation come from different regions students.

Computer science is an application-oriented discipline with rapid technological update and high engineering complexity. It has high requirements for its depth and interdisciplinary breadth, so a single teaching method cannot meet the society needs, nor meet the needs of students in the future employment. Other hand, students do not realize the importance of practice courses, have weak motivation and even weak innovation ability partially because of more theoretical than practicability on limited technology teaching platform.

The characteristics of Chinese college students are weak interdisciplinary comprehensive application ability, low innovation ability and critical thinking, few challenge and adventure spirit, and lack of motivation of knowledge exploration. They are used to learning alone, seldom inquire actively and discuss mutually, let alone teamwork cooperatively.

There is still a certain gap between status and the country's requirements for innovative talents, especially the cultivation of high qualified talents in computer science. College education should be the "downward extension of the society", not just the "upward extension of high school". The destination of college education is not only the accumulation and growth of high school knowledge, but also the adaptability and knowledge transformation ability after entering the society. Therefore, it is necessary to change teaching concept, adjust and re-establish the practice teaching program based on principle of student-centered orientation, considering social needs, taking personnel delivery as the guidance, supported by the constructivism theory. Therefore, under the new engineering background, we try to apply the "Two Learning and Two Education" cultivation mode to empower the practical education of computer innovation and entrepreneurship talents.

3 Cultivation Mode and Framework Introduction

Explore the new practice teaching mode, "CBL (Case-Based Learning)" and "PBL (Project-Based Learning)", supported by the constructivism theory [2, 3], the theory of combining concept and specific situation to form a conceptual framework, shown in the below Table 1, fill abundant instances in each concept or involve multiple concepts, continuously raising students' intelligence from one level to another higher level, and really keeping teaching ahead of development. Students can gradually build their own knowledge framework and form their unique mental model in this kind of learning, which is also conducive to improving students' ability to solve problems and their sense of critical thinking and innovation.

In order to help students quickly adapt to society or independently start a business, we take student-centered as the key of constructing the curriculum system, put forward two exporting modes of "Competition Inspire Education" and "Industry Cooperative Education" which really put "Internal Cultivation and External Introduction" idea into practice. We increase the ratio of external application teaching starting from the junior year, encourage the students approach society, widen their vision, realize the gap between society needs and their abilities as early as possible.

Table 1. MODE framework

Mode	Teaching Objectives
Case-Based Learning	• For freshmen, lay a good foundation and master learning methods • For sophomores, repeated practice then continuously understand in-depth
Project-Based Learning	• For freshmen, understand the project development process and consolidate the programming foundation • For sophomores, strengthen the practice and constantly improve the technical ability • For junior students, focus on actual combat training to exercise teamwork ability
Competition Inspire Education	• For freshmen, select the potential students for personalized training • For sophomores, improve innovation sense constantly by participating competitions • For junior students, improve the ability of complex problem solving by actual combat training • For senior students, find the right interest direction, then continuously research in-depth
Industry Cooperative Education	• For junior students, research industry needs and learn cutting-edge technology • For senior students, improve innovation ability through the enterprise project internship

4 Connotation of Cultivation Mode

4.1 OTO (Online to Offline) Simultaneously CBL (Case-Based Learning)

To cultivate the mental model and computational thinking needed by innovation and entrepreneurship talents under "new engineering". The core skills of computational thinking include creativity, critical thinking, algorithmic thinking, problem solving and cooperative learning. Under computer graduate practical teaching system, we have constructed the laboratories of digital circuit, computer system, network engineering, embedded system etc., built the experiment platforms of EDA, RISC-V processor design, RISC-V embedded MCU, network virtual test system, artificial intelligence test system, online evaluation system etc., designed some experimental resources case libraries of remote control car, intelligent car, agricultural robot, service robot etc. These practical teaching platforms, open sharing and "virtual and real" integration, provide students with a real practical environment for free exploration. We have designed a batch of classic cases based on RISC-V, artificial intelligence and embedded new technologies. These platforms and accumulated cases can reshape the mental model and computational thinking of undergraduates, and lay a solid foundation for project-based learning later [4, 5].

As an example of "Obstacle avoidance car" to explain, which consist of RTOS system, RISC-V chip, ultrasonic construction and GPS indoor and outdoor obstacle avoidance car, it help students touch the field advanced technology, master the working principle of digital system, but also experience the new technology application and the intuitive effect.

4.2 Structured PBL (Project-Based Learning)

According to the innovative talents growth law, we have designed a progressive and elaborate training mechanism, which put the concepts including basic, comprehensive and innovative education through each experimental teaching phase. As a new paradigm of engineering education of CDIO (Conceive, Design, Implement, Operate), PBL contains the knowledge of computer, software engineering, IOT, AI, network security, electronic information and other subject areas. It covers four grades and each stage of undergraduate computer major, and shares the projects of RISC-V embedded system, non-contact transportation robot, medical imaging AI system, big data of Traditional Chinese medicine etc. It lays emphasis on engineering consciousness and engineering thinking training for lower grade students, on engineering ability and system ability exercise for junior and senior students, finally develop to form the ability training model based on CDIO computer system [6–9].

As an example of "RISC-V embedded systems" to explain, students can comprehend RISC-V command system, completely learn the processor design technology, understand the EDA technology and master the whole process of design and development of the embedded system. Finally they can form an overall outlook, system view and design thinking of computer project, also can gradually form the problem solving skills of complex engineering problems.

4.3 "Competition Inspire Education"

Adhering to the new concept of open source in innovation education, we are exploring a dynamic practical education training mode that integrates maker platform and discipline competitions to achieve a win-win situation of "promoting learning, research and production through competition". In terms of implementation, discipline competitions are exercised in the online and offline open laboratory platform of OSS and OSHW with keeping continuously updating construction. The competitions are 4C, Lanqiao Cup, ICT, CITI Cup, IOT Contest, Internet + IEC, outsourcing service IEC, AI Creativity Contest etc., and outstanding achievements from the competitions can be transferred to the high quality cases imported into experiment platform to be used by colleague freshmen. Through this training mode, students' learning enthusiasm is stimulated, personalized ability is developed, independent learning ability and innovative scientific research consciousness are enhanced, and high-quality top-notch talents with "three innovation" ability are cultivated through discipline competitions, and the core competitiveness of computer professionals is constantly improved.

As an example of 4C competition to explain, it covers more than 10 categories such as software development, internet application, AI application, big data application, information visualization, digital media etc., Some competition topics are assigned by enterprises about multiple areas of technology application, make the college students can know about the actual demand of enterprise and cutting-edge technology. Through years of continuous participation and practical training in the university, quite a number of achievements have been accumulated and applied already, students' innovation consciousness has been constantly sublimated.

4.4 The "Industry Cooperative Education" Alliance of Colleague-Enterprise-Local Government

For pushing innovation education mechanism with social demand orientation and multidisciplinary integrated education, we have put forward the proposal of industry-college alliance which is communication between campuses, industry-college cooperation and countryside construction participation. Under the slogan of the "go out and come in", we have developed the advantage resources of well-known universities, IT enterprises and local government departments in order to broaden exchanges channel between internal and external teachers and students, then promote the external radiation spread of practical teaching and rapid transformation of research achievements [10, 11]. We have built the intelligent base, the RISC-V joint laboratory of processor design, carried out the mechanical arm joint construction and study of innovation platform with some intelligent companies. We have also led students into the countryside enterprises during summer and winter vacation under the aid of alumnus, inject new impetus into the development of science and technology and rural development. All these have brought new ideas and broadened horizons for students' experimental training, extra-curricular scientific research interests, innovation and entrepreneurship training, discipline competition and entrepreneurship practice. It has formed mature and extendable experience of "Industry Cooperative Education" alliance of colleague-enterprise-local government.

As an example of the intelligent base to explain, the enterprise provides students with hardware resources of Arm Server, AI Server, and software resources of Cloud Platform, Open Source Operating System, Open Source Applications etc., Through teacher training and teaching research, joint development of curriculum resources, the construction of practice training platform, we have provided the students more chances to approach the cutting-edge industrial technology, accelerated the transformation from theoretical learning to practical application, shorten students' social adaptive period.

5 Practice Effect Analysis

5.1 Teaching Practice

The practical education cultivation mode of "Two Learning and Two Education", which adopts grading and classification to construct experimental teaching resources, shown in the below Fig. 1, needs to be constantly improved in the implementation process, and its core is to achieve good learning effect for students.

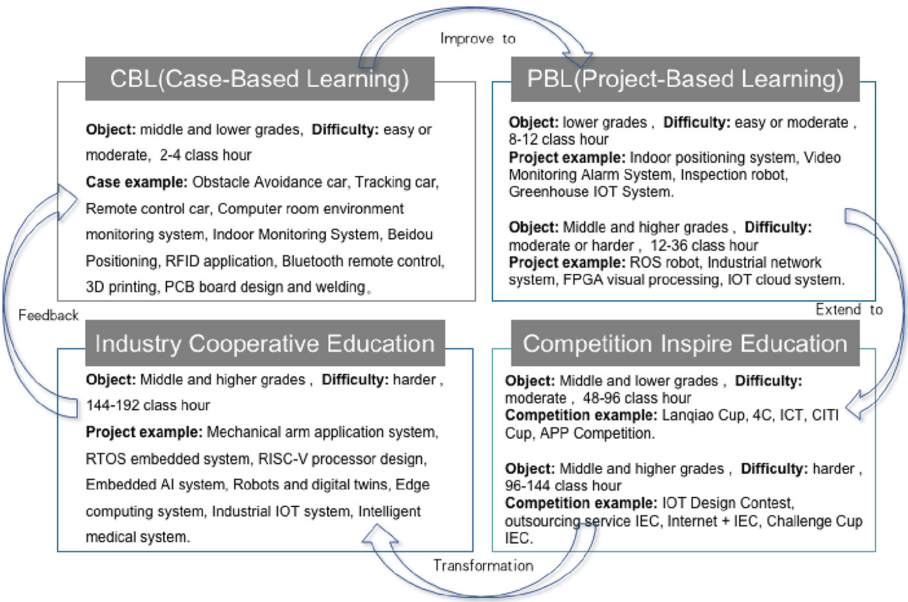

Fig. 1. The content of "Two Learning and Two Education" mode

By optimizing the practical teaching team, taking the resources of mass innovation experimental project as the breakthrough point, the experimental teaching team composed of teachers undertaking scientific research tasks, experimental technicians, graduate tutor, outstanding student entrepreneurial teams, technical backbones of cooperative units and enthusiastic alumnus are integrated to participate in the design of high-quality experiments. We will continuously refine and transform teachers' scientific research achievements, real projects of cooperative units and award-winning works of previous competitions to form high-quality practical teaching resources.

5.2 Affect Analysis

By cooperating with more than 30 enterprises and institutions, university-enterprise joint laboratory and university-enterprise cooperation practice base, carrying out social practice activities in countryside such as RuYang, XinYu and GanZhou, pushing the Competition Inspire Education mechanism, we have derived hundreds of experiments design projects, provided innovation and entrepreneurship teaching resources for more than thousands students in our university, and created practical opportunities for students to get on and off campus internship. It has also played a good role in sharing and spreading in other universities.

Under the background of "new engineering oriented" computational thinking and system ability cultivation, "Two Learning and Two Education" cultivation mode can realize the hardware and software collaboratively support and interdisciplinary integration, gradually cultivate the students' system view, engineering thinking and innovation ability, have sprung up a batch of outstanding students entrepreneurial teams like PaiYo Programming Puzzle team, MingYa IOT Maker team, Wufan Liangpin team, Wuyou Alumni team etc. In recent years, the number of students participating in "Internet+" IEC, 4C, and other contests is substantially increasing, the project quality promoting a lot, approved innovation credit application number increasing. According to incomplete statistics, more than 200 items national award has been won in the discipline competitions, as most as 800 person-time participate each year. These achievements are enough to prove that the "Two Learning and Two Education" mode has played a certain role in boosting.

5.3 Future Prospects

The "Two Learning and Two Education" mode in the process of experiment teaching after more than three years of practice, has initially formed systematically, but there are still some problems, especially in the new requirements of "new engineering" and AI new era, how to quickly adapt to the social demand for talents. Therefore, the practice teaching mode in the future need to increase the depth of the experiment teaching and theory teaching integration, form knowledge consistency and effectiveness. The content of CBL and PBL is more professional and keeps in touch with the industry's leading applications. In the process of continuous practice, we will take the problem as the guidance, and gradually revise, boost this mode to empower innovation and entrepreneurship education, which is suitable for the future "new engineering" talent cultivation.

6 Conclusion

In general, the "Two Learning and Two Education" practice teaching cultivation mode has its wide coverage, can be applied to interdisciplinary exchanges between students of this major and other majors. Secondly, its system is flexible, each part is not completely independent and mutually reinforcement. It can achieve a win-win situation for the country and talents. It can export computer innovative compound talents to the society through the four-year undergraduate education. It also provides valuable experience and high-quality resources for college students with entrepreneurial dreams. It has achieved some success in our college and can also be replicated and spread in computer education in other colleges. Of course, this mode still needs to be gradually revised and updated in the longer period of teaching practice, so as to continuously develop and improve, respond to the strategy of China's scientific and technological powerful nation and adapt to the needs of social development.

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Study on the Difficulties of Multi-campus University Student in the Practical Activities of Science and Technology

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Abstract. With the expansion of university scale, more and more universities choose multi-campus school running mode to enrich teaching resources, and the Chinese government proposes to speed up the construction of an innovative country. Based on the above background, universities pay more and more attention to the cultivation of students' practical application ability and the expansion of scientific research thinking. This paper adopts the methods of literature survey, case study, and questionnaire survey to analyze the research practice dilemma brought by multi-campus school running mode to students, and proposes solutions. At the same time, carried out practical exploration on two campuses of Zhejiang University of Science and Technology and achieved good results. This has a certain enlightening significance to the cultivation of applied talents in multi-campus universities.

Keywords: Multi-campus · Personnel training · Practical teaching · Project teaching · Science and technology innovation

1 Introduction

To meet the needs of rapid social and economic development in China, the scale of universities has been constantly expanding, and higher education has entered the era of popularization. Under the background of co-construction, cooperation, and merger, the lack of educational resources is an important factor for universities to expand the scale of running schools [1]. For the demands of construction and development, universities actively seek external development space and build new campuses in different places. Under the current background, the multi-campus model plays a greater role in integrating university resources, improving the level of university education, and alleviating the shortage of educational resources. Therefore, the multi-campus model is being adopted by more and more universities. As shown in Table 1, most universities in Zhejiang province adopt the multi-campus model of running schools, and most of them run schools in other places. With the deepening of education reform, society pays more attention to students' practical application ability and innovative thinking in research.

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Students' practical application ability and innovative thinking need to be cultivated through progressive project practice. Universities open independent practice platforms, encourage students to participate in scientific research projects, discipline competitions, patents, and other practical activities, improve the professional quality of teachers and practical guidance ability, and other measures to create conditions for the cultivation of application-oriented students [2,3].

Table 1. Campus establishment of undergraduate universities in Zhejiang Province

University	Campus Distribution	Whether a long-distance
Zhejiang University	Seven Campuses	Yes
Westlake University	A Campus	No
China Academy of Art	Three Campuses	Yes
Zhejiang University of Technology	Three Campuses	Yes
Zhejiang Normal University	Three Campuses	Yes
Ningbo University	Three Campuses	Yes
Hangzhou Dianzi University	Five Campuses	Yes
Zhejiang Sci-Tech University	Four Campuses	Yes
Zhejiang Gongshang University	Three Campuses	Yes
Zhejiang Chinese Medical University	Two Campuses	Yes
Wenzhou University	Two Campuses	Yes
Hangzhou Normal University	Three Campuses	Yes
China Jiliang University	Three Campuses	Yes
Zhejiang Ocean University	Two Campuses	Yes
Zhejiang A&F University	Three Campuses	Yes
Wenzhou Medical University	Three Campuses	Yes
Zhejiang University of Finance &Economics	Four Campuses	Yes
Zhejiang University of Science & Technology	Two Campuses	Yes
Communication University of Zhejiang	Two Campuses	Yes
Jiaxing University	Two Campuses	Yes
Huzhou University	Three Campuses	No
Shaoxing University	Four Campuses	Yes
Taizhou Univesity	Three Campuses	Yes
Lishui University	Tow Campuses	Yes
Quzhou University	A Campus	No
Zhejiang Police College	Two Campuses	Yes
Zhejiang Wanli University	Two Campuses	Yes
Zhejiang Shuren University	Two Campuses	Yes

2 Multi-campus Practice Teaching "Bottleneck" Problem

Multi-campus school running mode is a creative initiative for universities to broaden the space of development and enhance social impact. Under the condition of multi-campus, from the perspective of management, according to major subjects and student grades the school allocates students and educational facilities among different campuses. As a result, the subject nature and subject culture between campuses are uneven and the unified organic whole formed by each of campus still lacks comprehensive advantages in the performance of interdisciplinary integration. However, there are some problems with the project practice of students. As the project practice team members and mentors come from different campuses, the division of labor among team members, the confusion of project research objectives and plans, and the lack of project communication between team members and mentors make it difficult for teachers to control the phased research progress of student projects and project difficulties.

2.1 Teachers Aspect

The Problem of Limited Teacher Guidance. Multi-campus school running mode brings space inconvenience to teachers' guidance. Most faculty teach different majors, which are located on different campuses, and have limited guidance for students scattered across different campuses. There is a lack of communication between teachers and students in projects [4], it is difficult for teachers to control the difficulties and phased achievements of student projects, and students cannot understand the expected goals and development direction of teachers. In the case of decreasing interaction between teachers and students, the improvement of projects quality will be affected, and the projects achieved by students may deviate from the expectations of teachers.

The Problem of Restricted Teaching Management. There are unavoidable time and space barriers between different campuses [3], so teachers are inconvenienced in managing teams of students. The lack of project practice knowledge and ability development of junior students lead to deficiencies in the independent management of project practice, which require teachers to control and monitor their project research progress in real-time. Teachers are busy traveling among different campuses, and students are busy with the busy school curriculum. Under the obstacles of time and space, teachers and students actually spend less time on project discussion and analysis. It is also difficult for students to grasp the true intentions of teachers. The lack of effective communication between teachers and students will result in less positive feedback captured by students, which will affect their confidence in project cooperation. In the process of project development lasting a long time, most students will be inert.

The Problem of Increasing the Repetition of Teaching. Similar project problems were repeatedly emphasized in different campuses, which are greatly increased the workload of teachers in managing student team projects. The same project problems are repeatedly taught in different project teams on different campuses, which invisibly increase the amount of labor for teachers. Under excessive work, teachers' teaching model will gradually change, which is not conducive to the development of teachers' and students' innovative spirit in the discussion of project problems.

2.2 Students' Aspect

The Problem of Student Cooperation. Students choose their partners for project practice according to their wishes. At the same time, students are encouraged to form teams across grades and majors. However, whether teams are formed by grade or by major, team members may be distributed on different campuses, and there are regional inconsistencies in collaboration, which affect the progress and completion of team research projects. Student team project cooperation require the participation and discussion of all members. It is worth mentioning that it is difficult to find a time node and space region where all members are free. This will undoubtedly set obstacles for students' innovative practice projects and affect the development of students' enthusiasm.

The Problem of Inheriting-Helping-Guiding Lower Between Different Grades. *Inheriting-helping-guiding* is an effective and practical way for senior students to guide junior students [5]. Senior students help and guide junior students through the complete project development process, and recommend appropriate development software and knowledge to them. Lower grade students still have the mindest of high school. In the new environment of college life, it is necessary for higher grade students to guide them to carry out student project practice and cultivate the innovative thinking ability and practical ability of engineering talents. However, when senior and junior students are located on different campuses, senior students often have little time to discuss project experiences with junior students. There are only junior or senior students on the campus, which are not conducive to the healthy development of student teams. The senior students have rich experience in application practice, and the junior students inject fresh blood into the development of the team.

The Problem of Limited Sharing of Student Resources. It is difficult to share teaching resources, experimental equipment, and practice environments on different campuses [5]. Given the inconvenient geographical situation of the campus, the college will make appropriate adjustments to students' schedules. Some cross-campus courses may be postponed until students' sophomore or junior year. Due to differences in campus resources, there are barriers for students who participate in the project but are scattered across different campuses.

2.3 The Problem with the School Practice Platform

The construction of the practice environment is the basic element for students to carry out project practice. Before the practice environment is built, students may study in the cafeteria, dormitory, library, and these environments, which are conducive to the situation of students studying alone. However, it is unfavorable for the team to carry out project research and development and affects the progress of the team project implementation.

3 Influencing Factors

Student project practice enriches the teaching form of universities. The effectiveness of project practice is influenced by several factors, including teachers, students, and schools.

3.1 Teachers Aspect

Factors of Teachers Themselves. The new campus has a low amount of information, unsynchronized teaching resources, and low utilization of research resources [5]. Teachers are busy on different campuses for a long time to guide students' practice teams, which brings a great burden to teachers both physically and psychologically. In the process of guiding students, teachers not only supervise the progress of the project, and solve the difficulties of the project, but also include the process of teachers' emotional output and the ideological collision between teachers and students. Among them, teachers' emotional attitudes, academic attitudes, and scientific research styles have different degrees of influence on students' learning attitudes [6].

Factors of Professional Guidance Teachers. Although there is a help mode for senior students for junior students, the role of teachers' guidance can not be replaced. The development of a guiding faculty team not only promotes the improvement of students' scientific research and innovation level but also promotes the social service level of applied universities. While the school pays attention to the improvement of the ideological quality of teachers, it also needs to strengthen the improvement of teachers' ability to guide and teach application-oriented projects, which directly affects the cultivation of students' ability to practice and innovate projects.

3.2 Students' Aspect

Students are an indispensable part of project practice. Students' knowledge dimension, practical ability, teamwork ability, self-management ability, and other aspects affect the progress of research projects. Project scientific research practice is an extension of classroom theoretical teaching, which helps students to understand theoretical knowledge and improve their practical ability.

3.3 School Aspect

Factors of the Incentive System. A good system is a necessary guarantee for students' practice and teachers' project guidance. The necessary incentive system can stimulate the enthusiasm of teachers and students to participate in scientific research practice.

Factors of Practice Site. An independent environment is a basic element for students to carry out project practice. The practice base has necessary hardware equipment, and students can arrange their study time independently and carry out a theoretical study of the project independently, without interference from external factors, to ensure that students will devote all their time and energy to scientific research practice.

Factors of Traffic. While the multi-campus school running mode expands the scale of university operation, there is also the problem of inconvenient transportation between different campuses. Among them, multi-campus teaching brings great inconvenience to the scientific research practice of teachers and students. In remote school districts, campus commuter bus is a necessary factor to ensure the scientific research practice of teachers and students.

Factors of Campus Management Model Variation. The differences in campus management models have an impact on the adaptability of students and teachers on different campuses. A good campus management model can promote the development of the scientific research practice of teachers and students and is conducive to the personalized and independent cultivation of students' scientific research innovation ability. In the campus management mode, diversified laboratory management schemes are implemented, and students manage their learning progress independently according to their own needs, interests, and goals.

4 Solutions

Given the many problems of students in project practice under the multi-campus school running mode, the following three-level solutions are put forward: teachers, students, and schools.

4.1 Teachers Aspect

Teacher Training. In project teaching, teachers should have the ability to guide students. First of all, teachers should have a rich knowledge base, a broad scientific and cultural knowledge system, and a profound professional knowledge system. Expand educational thinking through continuous learning of new knowledge. Secondly, teachers also need to strengthen the ability of scientific research innovation and scientific research practice and provide technical guidance for students' scientific research practice. In addition, teachers should fully understand the interests, abilities, and needs of students, solve the difficulties of students' projects and grasp the direction of project research. Professional instructors can promote students' practical ability. The cultivation of teachers' guiding ability can be realized using expert guidance, teacher discussion, and guiding students' project practice.

Build a Teacher Studio. Professional teachers can promote the cultivation of applied students. The construction of the teachers' studio is aimed at improving teachers' project guidance ability and cultivating a group of teachers with rich professional knowledge and guidance experience. The studio collects and grasps the dynamic teaching situation and existing problems of teacher-guided student project practice, and conducts discussion and in-depth research based on this problem, to form a benign teacher team management system.

4.2 Students' Aspect

Develop Students' Interest in Project Practice. Interest is the source of one's continuous progress. Combine students' majors and interests to carry out project practice [7]. We develop students' interest in project practice and encourage them to participate in research competitions held by the university, province, and national innovation and entrepreneurship competitions. Students, driven by their interest in learning and honed by a period of project practice, can fully realize the importance of what they have learned.

Strengthen Students' Sense of Cooperation. The development and implementation of the project need students and teachers to pay a lot of energy and time. Students need to go through the stages of team break-in, project planning, and task division. For the teacher to better guide the students and the student team to work together more harmoniously, the teacher and team members need to understand each other's purpose of participating in the competition.

4.3 School Aspect

Create a Practice Platform. The practice base provides a place for students to carry out project teaching practice activities. Students learn theoretical knowledge in an independent and autonomous environment. The good learning atmosphere in the practice base promotes the cooperation of team projects and improves the quality of projects.

Designing a Project Practice Management System. In the process of project practice, the team will inevitably encounter project process management problems. The practice management system is designed so that team members can clarify the task planning process. The practice management system records the progress, completion quality, application of key technologies, and regular feedback information of the team in each stage of project research so that teachers can check the progress of project research in time and give corresponding guidance.

Adding Incentive System. The cultivation of application-oriented students needs benign system construction. Under the guidance of the benign system, the initiative of teachers and students to participate in scientific research projects is promoted to create a good campus atmosphere. Similarly, a positive campus atmosphere has a significant impact on students' abilities, innovative thinking, learning habits, and attitudes.

5 Practice and Effectiveness

Zhejiang University of Science and Technology is one of the first pilot units of the "Outstanding Engineer Education and Training Program" of the Ministry of Education of the People's Republic of China. It is committed to cultivating the practical innovation spirit and practical ability of engineering talents, and enriching the project practical guidance ability of teachers. The goal of engineering education at the Zhejiang University of Science and Technology is to cultivate students with a proficient technical foundation and a wide range of professional abilities [8]. In response to the problems of students in project practice under the multi-campus school running mode, the following practices are carried out.

First of all, we implement the management model of the school system on the campus and establish the "Blue Space" innovation practice base. Encourage students to take the initiative to participate in scientific research practice by combining their interests with their majors, to promote the cultivation of students' practical application ability and innovation ability. As shown in Fig. 1, Fig. 2 and Fig. 3.

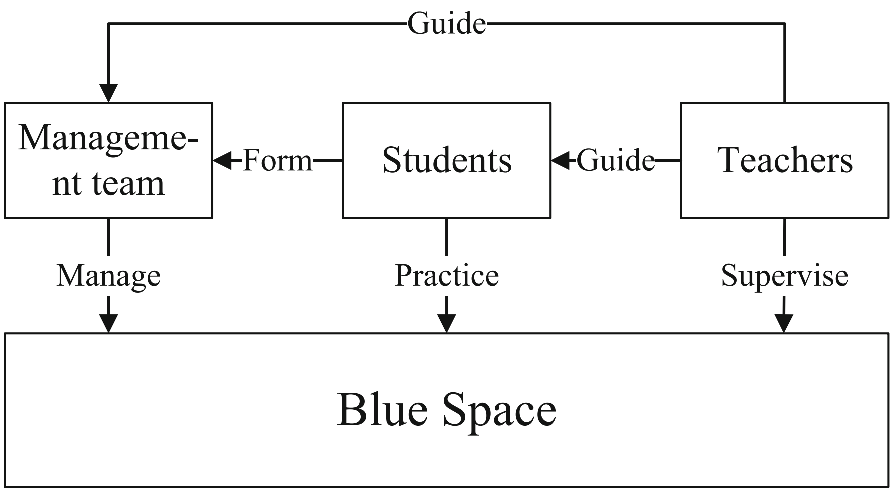

Fig. 1. "Blue Space" management mode.

Secondly, create a master studio to develop teachers' project-guided teaching ability and cultivate students' application practice and innovation ability. The studio is composed of provincial teaching master teachers and professional backbone teachers, and students choose their role tasks in team practice through their interests combined with their majors.

Furthermore, by expanding the construction of the practice environment on different campuses, students are free to deploy some of the equipment in the laboratories as well as have the autonomy to manage the practice base and laboratories, and the openness of the environment promotes students' sense of self-management. As shown in Fig. 3 and Fig. 4.

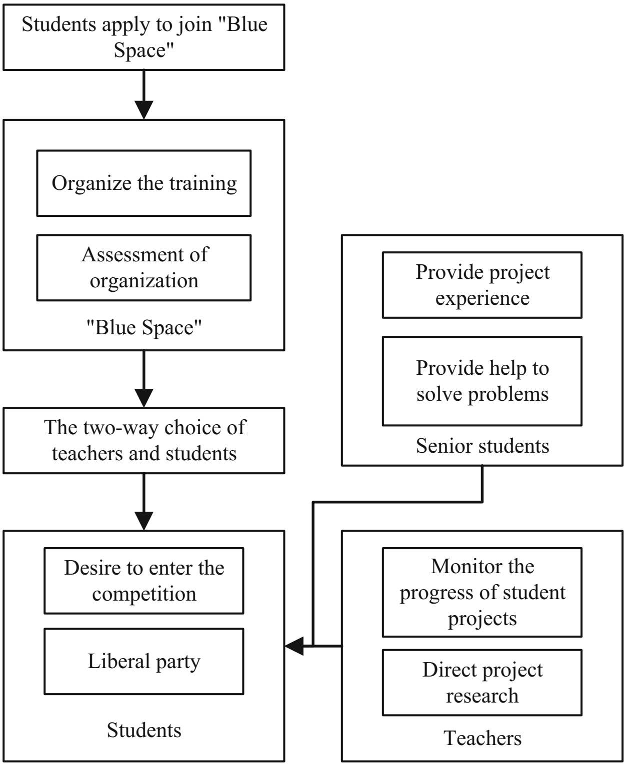

Fig. 2. The course of practice in "Blue Space".

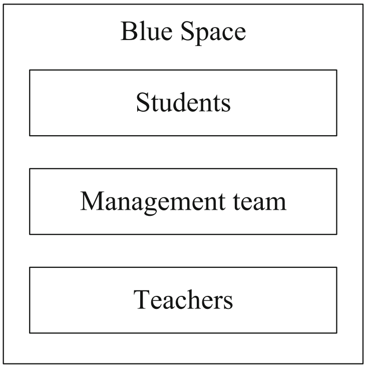

Fig. 3. "Blue Space" Personnel composition.

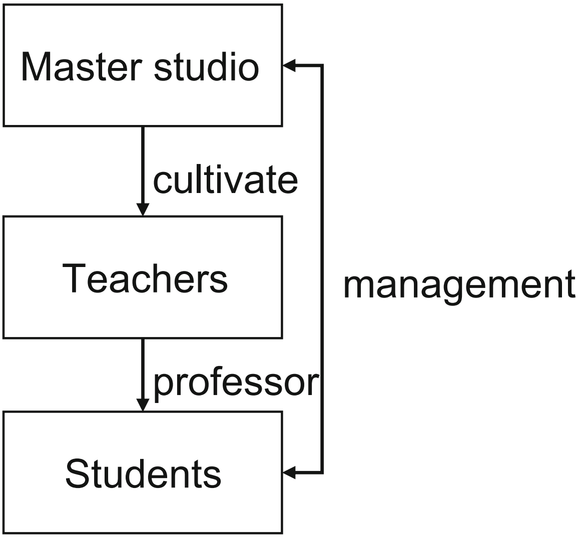

Fig. 4. Sketch of master's studio.

Finally, the design of a process-oriented management system for college students' science and technology innovation projects [9], realizes process-oriented supervision and management of student research projects by teachers, clarifies the problem of division of labor among teams and improves the progress of project completion.

With the help of the "Blue Space" student Practice innovation base, student practice teams such as "one Five Innovation", "Panda" and "Late Sleeper" have achieved good results in scientific research competitions and carried out innovative practice in the multi-campus context. Since 2015, each practice team has hosted 84 national and provincial practice projects, won 212 national and provincial discipline competition awards, published 87 papers, and authorized 37 software works and invention patents, fully completing the project process and achievement transformation of innovative practice learning. The base encourages students to study, drives students to participate in scientific research practice, and creates a good scientific research practice atmosphere for the school.

6 Conclusion

After the reform of the higher education system, higher education has developed from elite talent training mode to popular mode. In order to better serve society, colleges and universities began to seek to expand the scale of running schools, and multi-campus school running has gradually become the mainstream trend. The national demand for the cultivation of talents with practical and innovative abilities is increasing day by day. We must break through the dilemma of students' scientific research practice under the multi-campus school running mode. The corresponding countermeasures proposed in this paper have proved to be effective and have achieved the purpose of promoting the cultivation of students' practical abilities. At present, more and more universities join in multi-campus school running mode. Multi-campus school running mode has become the inevitable trend in the future development of universities, which is both an opportunity and a challenge for universities. Universities should be based on their own actual development needs, with the goal of training application-oriented and innovative talents, and pay attention to the construction of a practical environment while improving the practical ability of talents.

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Comparative Analysis of NMT and Human Translation
—Poverty Alleviation Perspective

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Abstract. With President Xi's stress of "telling Chinese stories well" in the new era and the increasing needs of economic and cultural exchanges among countries around the world, translation is playing a critical role in information transmission and communication. Accompany the emergence of Neural Machine Translation (NMT) based on deep-learning technology, artificial intelligence has made a great process in the translation. However, few scholars have made the comparison between NMT and human translation in the theme of China's poverty alleviation. To provide reference for the publicity of China's poverty alleviation stories, through comparison analysis, this paper explores the ways to improve the translation efficiency of artificial intelligence in this specific area.

Keywords: Neural Machine Translation · Human Translation · Deep-learning · Poverty Alleviation

1 Literature Review

With the development of information technology, we have gradually entered the era of linguistic intelligence. As early as 1954, the world's first written machine translation system appeared in the United States. After that, machine translation began to develop continuously with the progress of computer technology. In recent years, deep-learning technology began to rise, and neural network machine translation (NMT) based on deep-learning technology began to enter the public view. In 2016, Google released neural network machine translation system, and since then machine translation has entered a new stage of rapid development [1].

With the gradual improvement of machine translation accuracy, the comparative analysis of machine translation and human translation has gradually emerged. Most of the previous studies on the comparison between machine translation and human translation are macroscopic, and the differences between machine translation and human translation can be obtained by comparing the translations between the two, but the translation comparison in some specific fields are from enough. With the enhancement of China's international strength, more and more fields need to go overseas, so the comparative study of machine translation and human translation begins to focus on specific fields. This is reflected in many aspects, but generally there are the following aspects of comparative analysis.

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First of all, there are many comparative studies on machine translation and human translation from the perspective of literary text. Due to its high cultural connotation and aesthetic elements, literary text is more difficult for machine translation [2], research shows that machine translation lacks flexibility when translating the literature text, difficult to express the meaning of literature, and it often needs human intervention. Li Yao conducted a quality study on machine translation of the literary book Chronicle of a Blood Merchant [3], and emphasized that translation should be based on social and cultural background by comparing the density of vocabulary, the subject words, average length of words and average length of sentences. He emphasized in his research that translation should be based on socio-cultural background. Due to the different research methods and the different selection of texts, the research results varies greatly.

Secondly, the comparison between machine translation and human translation in national languages is not rare. Hari Danmu Abdukrim studied the translation quality of NMT in Uyghur and Chinese [4], and emphasized the importance of language resource base. Liu Yang studies the construction of parallel corpora for machine translation of small languages [5], and points out that the participation of human translation can build high-quality parallel corpora and greatly improve the quality of machine translation.

In addition, researchers also conduct comparative analysis of machine translation and human translation in the medical field. Jing Ning takes the terms of Huangdi Neijing as the research object and compared the results of machine translation and human translation [6], pointing out that, machine translation is difficult to accurately translate traditional medical terms compared with human translation. However, this study did not propose specific and feasible methods. Therefore, more empirical research is urgently needed to improve the translation efficiency of machine translation in terms of terms, which is not only required for medical terms, but also for the terms of poverty alleviation.

As the importance of spreading the Chinese voice in the new era increases, more and more political documents have been translated into English. Political literature is highly political, so it requires high accuracy [7]. Jiang Rong pointed out in his comparison between Google translation and human translation of political literature that translators can use Computer aided translation (CAT) to improve translation efficiency [7]. Currently comparative research for machine translation and human translation in the political literature is still insufficient, Chinese poverty alleviation story also belongs to the Chinese political literature, so it is in urgent need of political translation comparison of the use of NMT technology to improve the efficiency of political translation, so that we can know how to make Chinese stories spread out in a better way through researches about comparative analysis.

Finally, we found that machine translation is often applied to the text in the field of law, science and technology through the literature sorting. Because the structure of legal text and technology text is usually rigorous, the description is more objective, so the translation readability of machine translation will be worse in dealing with professional, complex and long sentences [8]. This reminds us that we should not rely too much on machine translation when translating professional words for poverty alleviation, but should improve the accuracy and readability of translation through manual post-translation editing.

In general, comparative research of machine translation and human translation is little in the field of poverty alleviation, and more new research is urgently needed to promote the dissemination of poverty alleviation stories and improve the ability of overseas translation of poverty alleviation texts. Moreover, while previous studies emphasized the importance of vocabulary corpus, this paper will also focus on the corpus to help our research. At the same time, comparing machine translation with human translation can help us fully understand the shortcomings of both sides in translating poverty alleviation texts, so as to constantly optimize the machine translation technology and better serve the overseas dissemination of Chinese stories.

2 Principles of NMT and Human Translation

2.1 Principle of NMT

From the above analysis of the literature, we can see that Neural Network Machine Translation (NMT) has led translation to a new stage of development, and the reason of NMT's wide use is that it adopts a more advanced translation model. We will briefly describes the principles of NMT in the following.

Neural Machine Translation (NMT) as a recent machine translation method, compared with the traditional Statistical Machine Translation (SMT), NMT uses deep neural network to realize the end-to-end overall translation mode, making the translation language more natural, and it greatly improves the accuracy and fluency. Because artificial neural networks need to be constantly fed from layer to layer to complete calculations, passing through several layers, this is a deep artificial neural network, and this kind of machine learning is called deep-learning. NMT uses machine deep-learning technology. Deep-learning, "machine learning based on artificial neural networks", refers to the learning of the internal laws of the sample data to enable the machine to have the same analytical ability as people. NMT is able to train a neural network that can map from sequence to sequence, and can output a longer sequence, which performs very well in terms of translation, dialogue and literal generalization. NMT is actually a encoder-decoder system. Encoder encodes the source language sequence and extracts the information from it, and then converts this information to another language, the target language, through decoder, so as to complete the translation of the language. In order for machines to have human-like thinking, it is necessary to understand the characteristics and advantages of human translation.

DeepL translator relies on artificial neural network technology for text translation. In this paper, the now popular translation software DeepL is used as the NMT paradigm to compare with human translation. Human translation mainly refers to the behavior of converting one language into another through human means. Unlike machine translation, human translation is a way to artificially control the quality of translation. Next, take the relevant content of "poverty alleviation" as a comparison of Neural Machine Translation and human translation to explain the difference between Neural Machine Translation and human translation. In this way we can provide reference for the publicity of Chinese poverty alleviation stories and explore the ways for artificial intelligence technology to improve translation efficiency in the context of language intelligence.

2.2 Advantages/Characteristics of Human Translation

Although the machine translation is popular in this time, human translation is still irreplaceable. Human translation mainly makes use of human subjective initiative to convert between languages, so one obvious feature that distinguishes it from the machine translation is that people have ideological consciousness and their thinking is more flexible than that of machines. They can flexibly think about and make improvements to the grammar application, sentence fluency and structure in the process of translation. The translation from human translation usually has strong readability, which can express the meaning of the original text to a greater extent and facilitate the readers' understanding. Therefore, the sentences translated by human translators are stronger than the results of machine translation in terms of grammar and logic.

Not only that, due to the large differences in social and cultural backgrounds of different countries, there are usually large differences in cultural environments and ways of thinking and expression between the two linguistic societies. But the machine translation, due to its stereotypical computing algorithm, finds it difficult to understand the differences between the two cultures and choose the appropriate language to express them, and they can only systematically produce translation based on the original text. However, human translators, due to their flexibility and subjective initiative, can combine the language usage habits and ways of thinking of the two societies and translate the translated text with flesh and blood, which makes it easier for readers to understand..

In addition, literary texts are often used as translation materials to promote the liberal exchange between different countries. The language used in literary texts is elaborate, the wording fits the overall context, and the atmosphere of the text is coherent, which can easily become dull and lose the context of the original text when translated by machines. Because it is difficult for the machine to recognize the context of the original text. The human translator can accurately grasp the meaning and context of the original text through his or her subjective initiative, and the translation is more appropriate.

However, the shortcomings of human translation are also obvious. Human translation completely relies on people to translate, and human energy is limited, so the speed of translation cannot be faster than the machine translation. Therefore, human translation takes a lot of time. Not only that, when translating some texts with strong professionalism and objectivity, the pursuit should be the faith to the original text, but due to the existence of subjective initiative, the translator is likely to translate by her own understanding, which may deviate from the meaning of the original text to a certain extent.

3 Comparative Analysis of NMT and Human Translation

We selected the representative poverty alleviation words as the object of our research and then input them into DeepL translator as an example of translation result of NMT. The term is also then translated by humans. Finally, the two translations are compared and studied to conclude the differences between them. By contrast, we found the following differences.

3.1 Verbatim Translation

During our analysis, we found that Neural Machine Translation and human translation are prone to verbatim translation differences when translating poverty alleviation words. The verbatim translation mentioned here refers to the direct literal translation of the words without correctly understanding the meaning of the original text, which leads to the lacking expression of the original text and even misinterpreting the meaning of the original text.

For example, "两不愁三保障", it has a special meaning in China as a characteristic word of poverty alleviation. "两不愁" refers to "ensure that the rural poor have no worries about food and clothing". "三 保 障" refers to "ensure the compulsory education, basic medical care and housing safety". However, in DeepL, the translation result of "两不愁三保障" is "two worries and three guarantees". Obviously, Neural Machine Translation directly uses verbatim translation in this word. It translates "愁" directly into "worries" and "保障" directly into "guarantees". However, it ignores the consistency with the original text, and also produces a missed translation. "Two worries" not reflecting "不愁", it directly omitted the meaning of "不", and misinterpreted the original meaning.

While human translation combines the meaning of the word itself, with no verbatim translation performing. It translates it into "Guarantee the basic needs of food and clothing for those living in poverty and ensure that they have proper access to compulsory education, medical care, and safe housing." Human translation is based on the meaning behind the poverty alleviation words, and the meaning of the words is relatively well expressed, which can describe the specific meaning of the poverty alleviation words and promote the publicity of poverty alleviation undertakings. However, human translation also has the problem of not concise enough, and its content is relatively long.

For some sentences about poverty alleviation in official government reports, there are also differences in verbatim translation between Neural Machine Translation and human translation. For example, "建设持久和平、普遍安全、共同繁荣、开放包容、清洁美丽的世界". This sentence expresses China's ardent hope for the success of international poverty alleviation and its call to build a community with a shared future for mankind without poverty and common development. This sentence is the content of the report of the 19th National Congress of the Communist Party of China, so the statement of this part should be precise.

In the Neural Machine Translation with DeepL as a carrier, it is translated as: Building a world of lasting peace, universal security, common prosperity, openness and inclusiveness, cleanliness and beauty". It translates "持久和平"、"普遍安全"、"共同繁荣"、"开放包容"、"清洁美丽" and a series of words into nouns. And it used verbatim translation according to space order. The hierarchy between words is not so high and it appears boring, obviously not suitable as a translation in the official report. Not only that, "建设" acts as a verb in this sentence, which should use the pattern of "to+verb" to express action, so the use of "building" in this sentence maybe questionable.

However, human translation translated the sentence as: "to build an open, inclusive, clean, and beautiful world that enjoys lasting peace, universal security, and common prosperity." Human translation uses "开放包容" and "清洁美丽" as adjective to modify the "world". It also interprets "持久和平", "普遍安全", and "共同繁荣" as nouns, but they further modify world in the form of attributive clauses. In the meantime, it uses "enjoy" to describe the good expectations for the future world. Overall, human translation is more suitable for use in official bilingual reports.

3.2 Proprietary Terms

When translating specialized words about poverty alleviation, it is more difficult for translators to weigh the degree of translation with reality. Insufficient translation will lead to the lack of information expressed in the original text, let alone a good interpretation of the major policies of the state. In particular, there are a large number of phrases and idioms in the sector of poverty alleviation. In the face of these languages, we should not only translate them accurately, but also actually get close to people's lives, and translate and describe them with down-to-earth words.

"扶贫同扶志扶智结合" is the fundamental way to win the battle against poverty. Here, "扶 志" refers to "help people build confidence and thought", and "扶智" refers to "help people acquire knowledge and technology". In the DeepL, NMT translated " 扶贫同扶志扶智结合" into "Combining poverty alleviation with helping the will and wisdom", which understands "志" as "will", the meaning of "purpose and ambition", and it clearly does not correctly express the information that the original text wants to express.

The result of human translation is "Poverty Alleviation Through Increasing People's Confidence and Helping Them Acquire Knowledge and Skills", which means "understanding" 扶 志 "as" increase people's confidence". Moreover, it understands "扶 智" as "help people acquire knowledge and skills". The results of human translation are based on the thinking and understanding of proprietary words for poverty alleviation, which can better convey the meaning of proprietary words than the results of NMT translation, and it can also correctly express purpose of poverty alleviation policy.

3.3 Omission of Translation

During our analysis, we also found that semantic mistakes often occur when translating words about poverty alleviation, mainly reflected in the lack of modifiers and lack of fine combination of similar words and then lead to omission of translation. The omission of translation is mainly due to the negligence of the machine system and the improper understanding of Chinese, which leads to the lack of modification, incomplete and inaccurate semantics. The vocabulary of poverty alleviation is not in common use in daily life, in addition, many words are constantly updated. If such words are not imported into the computer system, it will lead machines to understand translation with existing programs. When the machine encounters words that do not understand, it will calculate the comparison of sentence similarity through the machine memory to match the closest-meaning translation. If not, it can only skip the meaning of a word, which leads to the omission of translation.

Take "送教上门" as an example, the result of DeepL translation is "home delivery", the result of human translation is "send education to home". We can only feel the meaning of sending things home through machine translation, but the meaning of "teaching" is not reflected. This belongs to the omission of translation. Compared with NMT, human translation reflected the meaning of "teaching" accurately, fully expressed its original meaning.

Secondly, such as the term "建档立卡", which means the accurate identification and collection of information of subjects to be alleviated and then establish corresponding electronic files and databases to realize targeted poverty alleviation and the dynamic management of poverty alleviation. It is an important means in poverty alleviation work. It is a verb phrase due to "建" and "立", so attention should be paid enough to reflect the dynamics of poverty alleviation in translation, in order to accurately express the meaning of the original word.

The result of DeepL for the "建档立卡" is "File and card". Obviously, it only translated the two word literally, and missed the translation of two important verbs——" 建" and "立", failed to reflect the dynamic management process of poverty alleviation. Human translation for "建档立卡" is "poverty registration", in which "poverty" reflects that the object is the poor areas or the poor population; "registration" means registering the population of poor areas, expressing the way and purpose of "建档立卡", and it reflected the dynamic management of poverty alleviation work.

3.4 Part of Speech

In the process of comparing neural NMT with manual translation, we noticed that the form of language will change accordingly. In order to keep the correctness and accuracy of the translation, there are often conversions of parts of speech. Conversion of parts of speech refers to changing the part of speech of some words in the original text while keeping the original meaning unchanged, so that the translated text is fluent and natural, which conforms to the expression habits of the target language. However, sometimes, due to the incompleteness of corpus and other reasons, neural machine translation will lead to the wrong expression of the original text owing to the error of conversions of parts of speech.

For example, "讲好中国故事". In such an era of fierce competition for international discourse power, this sentence means telling Chinese stories in a good way, so that the world can know the real China. But in DeepL, the translation of this sentence is "Tell a good Chinese story". Obviously, the error of conversions of parts of speech have occurred in the translation process of Neural Machine Translation. The word "好" is directly defined as an adjective, and it is considered as an adjective to modify the word " 故事". However, in fact, the word "好" is used as an adverb to modify the word "讲". The result of NMT will lead to misunderstanding of our country by other countries. Human translation, on the other hand, combines the Chinese context, comprehensively considers the parts of speech of words, and translates the sentence into "Tell Chinese stories well". It focuses on the adverb "well", accurately and concisely express China's determination and confidence to spread Chinese stories, and explain China in an international way with a discourse system that westerners can understand and accept, so as to achieve the purpose of propaganda.

There is also the saying "幸福乡村惠民生", which means that a beautiful and happy village can make people's life better. The translation result of DeepL is "happy villages preferential people's livelihood". Here, NMT regards the word "惠" as the adjective " 优惠的, 特惠的" and translates the word "惠" into "preferential", which means to give an advantage to a particular person or group. This made a mistake in part-of-speech translation and distorted the meaning that the original text intended to convey.

In human translation, we translate "幸福乡村惠民生" into "Happy country benefit the people's livelihood" by combining the sentence meaning and relevant context. The word "惠" is processed into the verb "benefit", which means to be useful or profitable to someone. This processing is also more in line with the requirements of part-of-speech conversion. Therefore, human translation can be more flexible in terms of the accuracy of matching with the original text.

3.5 Translation Efficiency

When translating texts, we should not only pay attention to the accuracy of translation results, but also consider the time cost of translation. NMT translation can translate a 5,000-word Chinese text into English in one minute because of its fast computer operation, which can save a lot of time cost for translators. However, when it comes to human translation, the time for translators to translate a 5000-word article is uncertain. Translation time is largely influenced by text type, number of new words and other reasons. Therefore, the time cost is often much more than NMT translation.

Moreover, NMT translation is simple and easy to use. Users can get the translation results in a short time only by simple input. However, human translation has higher professional requirements for translators. Therefore, NMT is more suitable for the public in terms of difficulty.

All in all, NMT and human translation are highly complementary in terms of translation quality and efficiency. When translating high-standard translations, we can't just rely on one kind of translation, and the correct way is to combine them organically (Table 1).

Table 1. Comparison of NMT and HT.

Category	NMT	Human Translation
Verbatim translation	Direct literal translation; misunderstand the original meaning	It can effectively grasp the poverty alleviation situation, and the translation results are more accurate
Proprietary terms	Lack of adequate term files	
Omission of translation	Lack of key modifier translation	
Part of speech	Miscalculation of part of speech	
Translation efficiency	Language transformation efficiency is high; simple and easy to use	Low efficiency; long translation cycle; high requirements for translators

Through the above analysis of differences between NMT and human translation, we found that NMT's translation of poverty alleviation terms is often affected by lack of adequate terminology, misunderstanding of the original text and misjudging the lexical nature. After finding out the reasons for the effect of NMT translation, we should address each of them in a targeted manner. The following are the suggestions we have made through our analysis to improve the efficiency of NMT translation, with a view to contributing to the external publicity of the poverty alleviation cause.

4 Suggestions on Improving the Accuracy of Poverty Alleviation Translation Results After the Comparison

4.1 Establish a Term Database for Poverty Alleviation

Through the above comparison, we know that because there are many professional terms in poverty alleviation in China, it is difficult for machine translation to accurately translate these terms, which will affect the external publicity of the national poverty alleviation policy to a certain extent. Poverty alleviation vocabulary is a unique vocabulary in China. Many of the terms have not been translated or the existing translations may be updated, which requires us to constantly improve the terminology bank related to poverty alleviation and improve the accuracy of NMT terms. At the same time, in the process of translation, each user is authorized to make additions to the terminology database and be recorded in the terminology database after submission and approval. Therefore, the content of the terminology database is constantly optimized to provide different perspectives for the interpretation of poverty alleviation vocabulary, and increase the elasticity of NMT.

4.2 Use Linguistics Knowledge to Improve the Deep-Learning Algorithm

In addition, since NMT uses deep-learning technology to perform calculations, although it is technologically advanced, there is still a problem of misunderstanding the context of the original text and misinterpreting its meaning. Therefore, we need to continuously improve the algorithm of NMT to make it understand the meaning of the original text as correctly as possible. Deep-learning distinguishes the data by analyzing the input layer data, and the effect is much more efficient than traditional machine learning algorithms, but it is still part of the field of computer science. When applied in the field of natural language processing, we have to pay attention to the understanding of semantics.

Deep-learning should also improve the existing knowledge model by promoting the multi-disciplinary intersection between linguistics and computer science, and discovering semantic laws through multiple learning of linguistics theory. By creating a deep-learning algorithm with "temperature", we can enhance language processing and spread Chinese stories "with temperature" and "depth".

4.3 Using Computer-Aided Translation (CAT)

The previous comparison shows that human translation is significantly better than neural network machine translation in terms of translation quality, but its translation efficiency is usually very low. Therefore, in order to increase the translation efficiency as much as possible while maintaining the translation quality, it is a good choice to use NMT mainly and supplemented by machine translation. We can use computer-assisted translation (CAT) to improve the efficiency of poverty alleviation translation. In the process of translating poverty alleviation vocabulary, there are many phenomena of term duplication. CAT records the data entered by the translator in the backstage through the translation memory technology, and when the translator mentions the data a second time, CAT provides the previous translation results. For similar sentences, CAT also gives translators appropriate advice, which can greatly improve the efficiency of translation. At the same time, CAT can also identify the wrong words in the article, check whether the article has spelling errors punctuation errors, inconsistent terms and other low-level errors, and then provide feedback to the translator, which can improve the accuracy of translation and play the role of proofreading and review.

4.4 Enhance Translation Post-editing

From the above analysis, it can be seen that it is difficult to be accurate with machine translation, and it will make a series of low-level errors such as misjudgment of words and context understanding errors, which reflects the importance of translation post-editing. Since the current NMT technology is not enough to output completely, it is necessary to ensure the accuracy of translation when dealing with articles about China's international image such as poverty alleviation. Due to the great differences between Chinese and Western thinking and culture, it is difficult for NMT technology to identify the differences between input language and output language, which requires translators to conduct post-translation editing after NMT processing and organically combine NMT technology with human translation. The translator uses the human brain to think and to feel the cultural differences between the East and the West, further improves the output text, and pays more attention to the reasonable transformation between the two texts, so as to make the final translation more accurate.

5 Conclusion

However, the methods of improving the efficiency and accuracy of NMT translation still need to be continuously innovated and perfected. The above proposed method is only used as a reference for the results of this paper, and still has many shortcomings. First, the authors' own level has limitations due to lacking of enough professional knowledge. Secondly, the corpus of poverty alleviation studied in the paper is insufficient, and the results obtained may not be universal. Finally, the proposed method is not systematic and deep enough, so it needs to be constantly improved.

With the strengthening of China's national strength, the "going out" strategy is particularly important. It is the bounden duty of each of us to spread the Chinese stories well in the context of the new era. Making full use of NMT and human translation in the context of language intelligence will help us to spread China's poverty alleviation stories more efficiently. Poverty alleviation stories are an integral part of China's story. By properly translating these stories into English, China's experience in poverty alleviation can also be shared by the world. Moreover, the overseas spread of China's poverty alleviation stories also provides a sample of China for countries around the world. At the same time, it is also conducive to establishing China's image as a big country and enhancing China's international discourse power.

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How Can AI Promote the High-Quality Training of "Belt and Road" International Chinese-Language Talents

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Abstract. This study aims to give full play to the advantages of artificial intelligence in the field of "Belt and Road" international Chinese talent training, overcome the problems of poor talent training, explore the path of high-quality talent training, so as to promote the accurate matching of talent demand side and supply side, realize the effective allocation of education and teaching resources, build a diversified mode of talent training, and systematically provide high-quality talents for "Belt and Road" construction. This study has certain reference value for the reform of talent training system and policy formulation in colleges and universities.

Keywords: artificial intelligence · Belt and Road · international Chinese language · talent training

1 Introduction

Since the belt and road initiative was proposed, China and the other countries have achieved great success over the past nine years:The idea of "one belt and one road" has been accepted by the international community and the international consensus has been expanding. By the beginning of 2022, China has signed 205 articles with 147 countries and 32 international organizations; Infrastructure construction continued, with a direct investment of 936.69 billion yuan in 2021 and 560 newly signed projects with a contract amount of more than 100 million US dollars; Outstanding achievements were made in economic and trade cooperation and the total trade of One belt & one road reached to 11 trillion and 600 billion yuan by 2021; With the continuous development of financing

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level and the gradual enhancement of capital guarantee, bilateral local currency swaps have been established with 21 countries, RMB clearing business has been established in 8 countries, and RMB cross-border payments cover more than 60 countries and regions; The level of people to people and cultural exchanges and cooperation with countries along the line has reached a new level, According to National Information Center Data.

However, these achievements are also accompanied by a series of problems. Summarizing the experience and lessons learned since the "Belt and Road" initiative was proposed, China put forward the requirements for high-quality development. Among them, the problems of talent training are as follows: 1. Talent training is overbroad and lacks pertinence. The development of the "Belt and Road" has continuously expanded the scale of talent training, and the demand for talent market has not been fully considered; 2. Talent training lacks stability. Because of the impact of the COVID-19, there are also some projects of the "Belt and Road" that are not planned to be carried out [1], the rupture of talent demand has caused the waste of educational resources; 3. Talent training lacks institutional construction, lacks rule guidance and planning coordination and so on.

As a public good provided by a responsible country to the international community [2], the Belt and Road Initiative not only reflects the common aspirations of developing countries to promote economic and social development through industrialization, but also provides a broad application field for advanced science and technology in developed economies. The era of Industry 4.0 represented by information technology is coming. Technology not only reshapes human life, but also promotes the reform of education. Reshaping the education system through technology has become a strategic choice for countries all over the world [3].

Based on this, this paper attempts to present the "Belt and Road" international Chinese talent training problems from the perspective of artificial intelligence technology; The data mining, analyzing and database construction of the "Belt and Road" talent training are studied; The algorithm solution of the "Belt and Road" international Chinese talent training is discussed; A systematic talent training ecosystem is formed and the high-quality development of the "Belt and Road" and the construction of a community with a shared future for mankind will ultimately promoted.

2 Dilemma of "Belt and Road" International Chinese Talents High Quality Training

On the basis of consultation, co-construction and sharing, the "Belt and Road" focuses on policy communication, unimpeded trade, facility connectivity, financial integration and people-to-people communication. The construction involves finance, law, transportation, energy, machinery and other fields, which puts forward new requirements for the quality of talents. The connotation characteristics of the "Belt and Road" international Chinese talents have also undergone a fundamental change, from a single language talent to a compound talent of "Chinese +". Talent is an important support for the high-quality development of the "Belt and Road". The training model needs structural adjustment, and artificial intelligence has become the key to solve the problem of talent training. Therefore, from the perspective of artificial intelligence technology, this study carefully studies the dilemma of talent training, carefully analyzes the entry point and possibility of artificial intelligence to solve these difficulties, and explores how artificial intelligence can promote the high-quality training of international Chinese talents.

2.1 The Abundance and Scarcity of Talent Training Data

The Demand for Talents in International Chinese Lacks Data Support
While the "Belt and Road" has brought global economic growth, it has created a large number of jobs, which have new requirements for the quality of talents. The teachers cultivated by educational institutions such as Confucius Institutes are obviously no longer able to meet the needs of the job market. The talent training model is facing a strong demand for international transformation. At present, the research on the demand side of talent has just begun, and the reform of talent supply side lacks sufficient data support. Pro. Zheng Tongtao and other scholars have long realized that it is necessary to carry out data collation of talent demand, and clarify the characteristics of talent demands through data mining and field investigation. The actual data of the "Belt and Road" international Chinese talent market demand is still very scarce [4].

Imbalance Between "Belt and Road" Data and Talent Training Data
Since the Belt and Road initiative was proposed, various data have been relatively perfect. The State Information Center releases the Belt and Road Big Data Report every year, and special reports based on the report, such as "The Belt and Road Initiative Report on Five-connective Index" are increasing. In sharp contrast to the great abundance of "Belt and Road" construction data, "Belt and Road" talent demand data is very limited. Many scholars have conducted relevant studies, which are beneficial attempts to analyze talent demand, and have accumulated valuable data resources, but perfect data collection still requires more efforts.

Absence of "Belt and Road" Talent Training Special Database Construction
The "Belt and Road" talent training database can realize the balance of talent supply and demand information, and support the formulation of talent policies. At present, the construction of talent database mainly has the following problems:

First, the technical problem of database construction. Data cloud platform contains three layers architecture: Iaas, Paas, Saas and five core functions: data collection, data analysis, data storage, data service. It also needs to consider multiple heterogeneous data fusion, because "Belt and Road" construction is developed within the international scope and need to break through resources, mechanism, standards and language barriers, to optimize the existing technology.

Secondly, the content construction of the database. The existing international Chinese education database is mainly teaching resources, such as the intermediary database which serves teaching, teaching case database, etc. Now, some major cities have realized the signality of database. Based on the big data, Shanghai has established talent policy database; Shenzhen will build talent big data platform; Nanjing began to explore international talent database. The "Belt and Road" talent training thematic database still needs to be built.

2.2 Extensive Application and Fragmentation of Talent Training Technology

Strengthening and Obstruction to Education by the Use of Technology
Technology use has permeated every link of education. For example, the audio-visual technology widely used in the classroom and all kinds of teaching videos and audio belong to cold media. Cold media brings a single transmission of information, which reduces people's communication and affects talent training. Through the analysis, it is found that these technologies do not fully consider the international Chinese teaching rules, and lack the necessary steps of education technology, resulting in the limited teaching effect, and become an obstacle to the development of education.

The Expansion of Technology to Space and the Deviation from the Essence of Education
Internet technology has expanded the space for teaching. Since the outbreak of COVID-19, online teaching has become a trend of future education. Online education follows the law of knowledge dissemination and gives full play to the role of network media. However, the education process is not only knowledge dissemination, but also the influence of knowledge on students. At the same time, online education makes students less engaged, and many students do not open the audio and video in class, which makes it difficult to ensure the teaching effect [5].

2.3 Talent Training Modes Are Various but Lack of Systematization

The Construction of Talent Training Mode Lacks Data Base
The construction basis of the previous talent training mode: first, a summary of the past talent training experience; The second is to learn from foreign experience, such as the talent training mode of Goethe Institute and French Union. In fact, there are already mature experience in talent pool construction in the world, such as the American Higher Education Database and the RAND Think Tank, etc. These reflect that the current talent training mode mainly from experience and lack of data foundation.

The Teaching Mode is Relatively Micro and not Systematic
The "Belt and Road" presents different needs in the construction process, which determines the difference in talent training mode. Not only the talent training model of globalization, regionalization, and nationalization is needed, but also the talent training model constructed according to the industry and level. At present, the research on talent training of the "Belt and Road" focuses on the teaching model, and there is less research on the systematic construction of the talent training model.

The Talent Training Model Lacks Institutional Construction
The main connotation of the high-quality development of the "Belt and Road" lies in sustainable development and institutionalized construction. To play the role of the talent training model, a sound mechanism must be built. Due to different market demands such as national cooperation, social needs and individual learning, the talent supply chain

needs to be optimized and upgraded. According to these problems, the country needs to carry out policy support and comprehensive layout, and colleges and universities need to build an interdisciplinary talent training system and form a systematic talent training plan [6].

To sum up, based on the perspective of artificial intelligence, under the background of high-quality development of the "Belt and Road", there is insufficient data support for the training needs of international Chinese talents, the special database for talent training has not yet been established, and the construction of talent training models lacks a systematic computing basis. The development of artificial intelligence in the future will bring the possibility of solving these problems. According to the laws of education, the need-oriented and student-centered talent training is the key to solve the problems, and it is also a direction worth striving for.

3 AI and High-Quality Training of "Belt and Road" International Chinese Language Talents

The high-quality development of "Belt and Road" poses new challenges to talent training, and the following three problems need to be solved: (1) What kind of talents to cultivate. Docking with the actual needs of "Belt and Road", summarizing the characteristics of talent demand, (2) How to train talents. How to realize the optimal allocation of educational resources and build a precise talent training mode, (3) Who will train these talents. To study the changes brought by the internationalization of "Belt and Road" education to education subjects, the following studies will be on how technology plays a role in talent training.

3.1 Reshaping of the "Belt and Road" International Chinese Talents Cultivation by Technology

Since the emergence of the information technology revolution, people hope that technology can promote the innovation and development of education, promote the reform of teaching methods, teaching content, teaching process, and teaching forms, so as to solve the problems of modern education. However, technology has been found to have a profound impact on social life and a limited impact on education. Reshaping education by technology means that a systemic change has taken place within education. The impact of computer technology on the cultivation of international Chinese talents in the "Belt and Road" is limited, because the laws of education are not fully considered: (1) Technology-oriented, adapting education to technology, which reverse the relationship between education and technology, (2) Education has a single use of technology and has little effect on educational innovation. (3) Technology deviates from the educational task, that is, cultivating and shaping people.

The key to the reshaping of education by technology is to follow the laws of education. In face of the impact of COVID-19 and the high-quality development of the "Belt and Road", technology can only reflect the principles of education in a systematic combination based on educational phenomena; adhere to the laws of education; propose a new set of solutions, methods or operating procedures [4]. Only in this way, practical problems can be effectively solved and the reshaping of the cultivation of international Chinese talents can be realized.

3.2 AI and High-Quality Training of "Belt and Road" International Chinese Language Talents

How to give full play to the role of technology and promote the high-quality training of international Chinese talents. The use of technology must go through the following three stages:

The Transition from Technology to Education Technology
Taking education technology as the goal, following the "Belt and Road" talent training rules, starting from the training concept, training objectives, training objects, training subjects, training methods and training evaluation and other elements and characteristics, according to new educational phenomena, carefully study which technologies have possibilities to realize the Technicalization of education.

From a Single Technology to an Educational Technology System
At present, technologies such as mobile Internet, big data, cloud computing, artificial intelligence, and even the Metaverse are gradually being applied to the field of education, which partially play the role of optimizing resource allocation and improving efficiency. To change the reform and innovation of education and teaching, it is necessary to form a complete education system technical system.

3.3 AI Promotes Changes in the Content and Methods of Talent Training

Back to the basic question of talent cultivation: first, what kind of talents are cultivated, and what are the distribution characteristics of these talents, such as industry, region, quantity, etc., field investigation and data mining are required, and a database is required too, which is the basis for AI generation. Secondly, AI solves various complex data through processes such as deep learning and knowledge graph cognition, and systematically builds an optimal talent training model. This is how AI works. Finally, according to the high-quality development needs of the "Belt and Road", the talent training model is innovated based on the calculation results, and iterative upgrades are achieved through the interactive process. This is how AI is applied.

4 High-Quality Training Path for the "Belt and Road" International Chinese Talents

This research aims to give full play to the advantages of artificial intelligence technology, promote the accurate matching of talent demand and supply, realize the effective allocation of education and teaching resources, build a diversified talent training model, and systematically provide high-quality talents for the construction of the "Belt and Road". Artificial intelligence works in three main steps:

4.1 The Construction of a Large Database for Talent Training: The Foundation for AI Generation

At present, there are three types of Internet databases: databases from the Internet, databases that use the Internet as databases, and databases connected to the Internet. Therefore, the construction of the “Belt and Road” international Chinese talent database follows the three principles: self-production, sharing and connection, and at least needs to contain the following three aspects of data:

“Belt and Road” Talent Demand Data

With the continuous development of the “Belt and Road” construction, a large number of talent gaps have been generated, and perfect talent demand data can provide a basis for the allocation of educational resources, talent management and decision-making. Therefore, we should accurately grasp the spread of Chinese in countries and regions along the “Belt and Road”, and dynamically monitor the international Chinese talent demand market through Python data mining technology [8]. Including the following aspects:

(1) Heat rendering. When learners have Chinese learning needs, they search, browse, share and discuss this information through the Internet, which reflects the learner’s hot spots and learning enthusiasm, (2) Tend to present. Data of learners’ discussion on social media can present their emotional leanings, (3) Media attitudes. The attitude of the official media of countries along the “Belt and Road” towards Chinese will affect their people. Based on online search, social tools and traditional media, the index system can fully reflect the learning demand situation of the “Belt and Road” international Chinese, and form a dynamic monitoring module for data. At the same time, the survey of relevant enterprises and educational institutions and the data mining of the recruitment network will finally present the number distribution, industry distribution and geographical distribution of the “Belt and Road” international Chinese talent demand (Fig. 1).

Fig. 1. Word cloud of BRI in Indonesia

For example, based on the Scrapy framework and with the help of Selenium, the crawler is able to send queries to the website and get the data returned. With this crawler, about 1000 tweets concerned with Indonesia and Belt and Road Initiative will be able to get. All the tweets’ texts can be used to create a word cloud to visualize the importance and frequency of different specific words. From the word cloud, that which words are more connected with Indonesia and BRI can be see directly (Fig. 2).

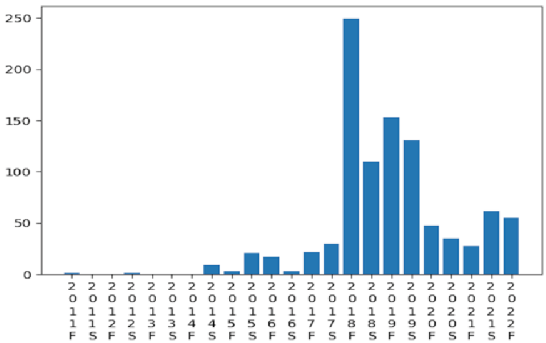

Fig. 2. Time distribution of the tweets in Indonesia

The timestamps were also used to plot a bar graph to show the time distribution of the tweets which indicates that BRI is popular in Indonesia in 2018 and 2019. The graph was designed in discrete half years. For example, 2018S represent the second half-year of 2018. And the height represents the number of tweets in that period of time.

"Belt and Road" Talent Characteristics Data

The analysis of the data on the characteristics of students' learning behavior has become an important reference for changing the way of learning. At present, various data platforms and monitoring systems provide a good foundation for the collection and analysis of teaching data. The system can collect multi modal data such as students' classroom behavior, psycho-emotional, and physiological indicators in real time to reflect students' learning status [9], which can be warned in real time. Researchers such as D'Mello have developed a set of learning behavior characteristic measurement methods for students' emotional and cognitive states, that is, AAA methods centered on advancedness, analyticity and automation [10].

Through the sensor to record the student's physiological data in the learning process, such as heart rate, blood pressure, brain waves, etc.; through the network log to understand the student's learning technology characteristics; through the wearable device to detect the student's eye movement, and then analyze the student's cognitive load and emotional state. Finally, the students' mental state is dynamically assessed based on this data.

"Belt and Road" Talent Training Data

Finch views talent development as a complex dynamic system, dividing students' learning backgrounds into 4 first-level indicators and 12 second-level indicators [11]. These indicators include political cooperation, trade and investment, and cultural exchanges at the national level; historical geography, ethnic religion, and language policy at the regional level; school communities, age occupations, and economic conditions at the individual level. According to these division indicators, the talent training data can be mined, and the data processing such as assignment can be carried out, and then classified and stored to facilitate the extraction and operation of the data. After all, the talent training database is the basis for artificial intelligence to produce and operate.

4.2 B. Database-Based Talent Training Model Construction: How to Operate AI

The "Belt and Road" database composed of different modules such as talent demand data, talent characteristic data, and talent training data which has constructed a knowledge graph for the cultivation of international Chinese talents, and provided a data foundation for the deep learning and reasoning decision-making of artificial intelligence. AI technology already has good performance in terms of computability, dynamics and interpretability, and can be intelligently modeled based on talent databases. Combined with the modeling steps of complex dynamic system theory, the pattern construction is completed by the five-step modeling method, including five steps, three-level pattern and three-layer system.

First of all, the five steps of the construction of the talent training model are: (1) determine the main elements of the talent training system, including six major elements: the training concept, training objectives, training content, training method, training subject and training evaluation, (2) determine the time dimension and social dimension of talent training, (3) describe the dynamic relationship between the elements of the international Chinese talent training system, showing its correlation and significance, (4) Observe the role and self-adjustment of the talent training system and the environment, (5) Describe the dynamic development process of talent training elements and environment and its emergent characteristics, and build a talent training model.

Secondly, the three-level model of talent training: (1) global talent training model. According to the international environment construction model, we will deal with the problem of talent training at the national level, (2) regional talent training model. According to the "Belt and Road" construction institute and the different backgrounds of the six major regions, six models have been constructed to deal with the problem of regionalized talent training, (3) national talent training model. According to the national conditions of countries along the "Belt and Road", we will build a foreign talent training model.

Finally, the three-tier system of talent training: (1) compound application-oriented talent training model, with colleges and universities as the core and to be complete through academic education, (2) elite talent training model, with research institutes and think tanks as the core to cultivate high-end policy talents, (3) basic practical talent training model, through vocational and technical education with Chinese as the carrier to create a three-dimensional model of talent training.

4.3 C. Application and Upgrading of Talent Training Model: How to Apply AI

Based on artificial intelligence algorithms, the demand-driven international Chinese talent training model mainly promotes the high-quality development of the "Belt and Road" through two ways.

First of all, artificial intelligence promotes the reform of education decision-making mode and promotes the accurate matching of talent supply and demand. With the help of artificial intelligence technology, the characteristics of the number, region and level of talent demand in the "Belt and Road" international Chinese can be presented. Guided by talent demand, artificial intelligence establishes the goal of future talent training, promotes efficient, government and enterprise effective cooperation, docks the actual needs of the "Belt and Road" construction, and realizes the accurate matching of the supply side and demand side of talents.

In addition, artificial intelligence can also overcome the problem of traditional decision-making lag. For example, since the outbreak of the Covid-19, the globalization process has encountered resistance. The focus of the future work of the "Belt and Road" has shifted, and the goals and contents of talent training have also changed. Artificial intelligence can make decisions based on these changes in a timely manner, adjust the talent training model, and overcome the lag of manual decision-making.

Besides, artificial intelligence improves the effectiveness of education management and optimizes the talent training process. Artificial intelligence realizes efficient management of the education process through real-time monitoring and early warning systems [11]. It is concentrated in the teaching process, mainly including: (1) Personalized learning, and formulating personalized smart learning programs for students, (2) The role of the teacher is transformed, and artificial intelligence replaces part of the teaching function of the teacher, (3) Dynamic development of teaching models. Determine the teaching content according to the needs, build the optimal teaching mode based on the effect orientation, and flexibly handle the differentiated learning process of students [12], (4) Shift in the center of gravity of quality evaluation. The teaching model is already the best solution formed after the operation, and the focus of quality assessment has shifted from the teaching process to the focus on teacher development and student quality improvement.

5 Conclusion

The high-quality development of the "Belt and Road" has put forward new requirements for talent training, and the new generation of artificial intelligence technology has solved the contradiction between the supply side and the demand side of talents through the reform and innovation of talent training mode. This study studies how artificial intelligence promotes the high-quality training of talents, which has certain reference value for the reform of the talent training system and policy formulation of colleges and universities. In the future, efforts need to be made from the following aspects: (1) Continue to promote the innovation of artificial intelligence technology, (2) Create application scenarios for talent training models, (3) Improve the construction of the "Belt and Road" talent training mechanism, (4) Prevent security problems caused by artificial intelligence.

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Research on Co-construction and Sharing Mode of Curriculum Resources Based on Limited Crowdsourcing and On-Demand Monopoly

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Abstract. In view of the problems existing in the current teaching mode of Colleges and Universities, such as the lack of high-quality teachers, the weak adaptability of curriculum teaching resources and the low utilization rate, etc. In this paper, we propose a co-construction and sharing mode of curriculum resources based on limited crowdsourcing and on-demand monopoly. Specifically, the model by creating the core content set and the largest content set of the curriculum, to realizes the co-construction of curriculum resources to cover the needs of all participating universities. Then, through the consultation and cooperation to allocate the task of co-construction. Furthermore, through the "curriculum creation engine, real independent domain name and virtual website" and other technological innovations, to achieve personalized sharing according to the needs of different universities, and cooperates with 16 application-oriented universities in Anhui province to carry out MOOC co-construction curriculum construction and practical teaching reform. This paper introduces the construction, application and effectiveness of this model, which has a certain demonstration significance for the construction of first-class curriculum in Application-oriented Colleges and Universities.

Keywords: Limited Crowdsourcing · On-Demand Monopoly · Co-Construction and Sharing · MOOC

1 Introduction

At present, China's higher education is facing unprecedented challenges from globalization, popularization, information technology and shortage of educational resources. Du Yubo, the President of China Association of Higher Education, also mentioned in the 2020 Asia Education Forum that "The supply of high-quality resources of higher education is still inadequate and the distribution is not balanced. The contradiction between the single and extensive education supply and the diversified and individualized educational needs of the people is still acute" [1].The co-construction and sharing of curriculum resources has always been advocated and pursued by universities. It is also mentioned in the 13th Five Year Plan of National Education that "The country actively develops 'Internet + Education'. Integrating all kinds of high-quality education resources, promoting the universal opening and sharing of resources, encouraging

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teachers and students to co-construction and sharing high-quality resources, and accelerating the reform of educational service mode and learning style [2]".The appearance of MOOC has brought new opportunities and challenges for higher education [3]. Since 2014, the application-oriented universities in Anhui have begun to explore the construction of MOOCS and innovate the teaching mode. However, due to the talent training orientation of application-oriented universities, the characteristics of students and the structural shortage of teaching resources, if the existing MOOC course resources are directly used, there will be problems such as poor adaptability of courses, difficulty in sharing and unfavorable to their own development. Even the high-quality MOOC resources of famous universities may not be suitable for Application-oriented College Students. At the same time, since the design and production of MOOC curriculum resources require a lot of energy, the majority of college teachers are not willing to carry out MOOC curriculum construction. Therefore, how to efficiently carry out the design and application of MOOC resources has become particularly important.

In 2017, Anhui Application-oriented Universities Alliance clearly proposed to jointly carry out the construction of MOOCS with the idea of "co-construction, sharing, openness and win-win, first use before construction, combination of use and construction, priority of effectiveness and steady development" [4]. However, on the one hand, the application-oriented universities have developed rapidly, with more young teachers and a large workload of teaching; On the other hand, the lack of a sufficient number of high-level teachers and the mismatch between curriculum teaching quality and talent training objectives are more prominent in the teaching reform practice of professional courses. Therefore, how to make the relatively limited high-quality teachers and teaching resources play a greater role has become the focus of current research in Colleges and universities. At the same time, all colleges and universities, especially the teaching management department, from the level of teaching management and school construction, hope to summarize and highlight the characteristics of the University in the process of high-quality curriculum construction and teaching mode innovation, and fully show the achievements and advantages of the University's curriculum reform. Therefore, they are generally unwilling to share too many courses of other colleges and universities. To some extent, it also causes the problems of repeated construction of resources in application-oriented universities, low utilization rate of some MOOCS courses and structural shortage of high-quality resources [5]. Zhai zhenyuan, the President of China Association of Higher Education, also proposed at the 8th China University teaching reform seminar that "we should not use 1% of the courses for 99% of the audience. We should not turn the online courses into the course supermarket of famous universities, but should build MOOCS in a hierarchical and classified manner."

In order to solve the above problems, we should take the natural advantages of information technology into challenges and integrate information technology and teaching to promote teaching reform and improvement. Based on the guidance of Anhui Education and scientific research computer network, in the exploration and practice of more than a dozen application-oriented universities in Anhui Province, this paper puts forward a co-construction and sharing mode of curriculum resources based on limited crowdsourcing and on-demand monopoly.

2 Introduction

2.1 The Basic Ideas

The basic idea of the co-construction and sharing mode of curriculum resources based on limited crowdsourcing and on-demand monopoly proposed in this paper is "co-construction as the core, sharing as the purpose, swarm wisdom as the basis, platform as the support, and curriculum leader responsibility system". It can be understood as organizing high-quality teachers among colleges and universities to jointly building curriculum and teaching resources that meet the needs of colleges and universities in Anhui province. In addition, through the effective integration of self-built courses and resources with national high-quality courses resources, the curriculum and teaching resource database can be built for all colleges and universities to sharing. Furthermore, the independent course domain name and independent mixed classroom are adopted to ensure the independence of colleges and universities in sharing, as shown in Fig. 1.

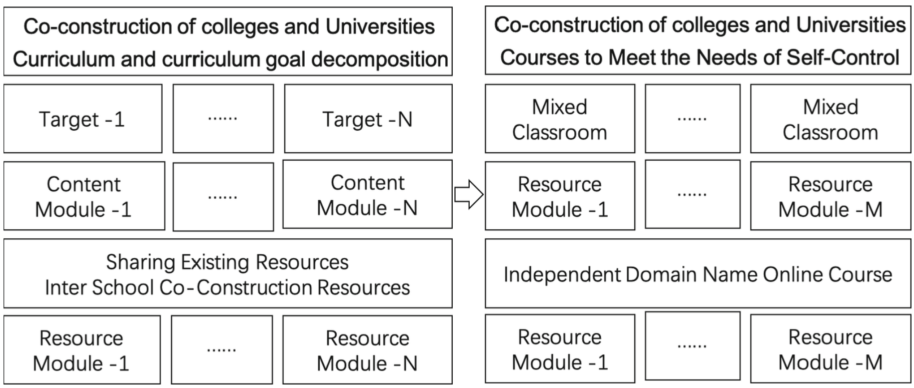

Fig. 1. The Co-Construction and Sharing mode of curriculum resources based on limited crowdsourcing and on-demand monopoly.

From the construction of curriculum resources to teaching implementation, management service and support platform, all adopt the way of co-construction and sharing. Teachers can add, delete and modify curriculum resources according to the actual situation to reduce teachers' investment and meet the needs of on-demand sharing. In the course implementation, flexible and diverse learning methods can be adopted according to the characteristics of students. Then, through the combination of online video watching + testing + discussion + offline flipping and practical training, students' computational thinking ability and application ability are cultivated; In addition, strengthen the management of the learning process, adopt the method based on Rubric peer evaluation and supplemented by teachers' random evaluation to evaluate the homework submitted by students, so as to give full play to the principal role of students. Furthermore, introduce subject competition and ability certification into the curriculum to promote students' learning through examinations and competitions.

Through co-construction and sharing, let excellent teachers can play a role in a wider range, so that more teachers can get better exercise through co-construction and sharing, and promote their development and growth. The same time, it can reduce the workload of teachers, including lesson preparation, writing teaching plans, making teaching courseware, etc. More importantly, teachers can build the curriculum and teaching resources aimed at cultivating application-oriented talents according to their own requirements, so as to promote the reform of curriculum teaching. Furthermore, by building a mixed teaching model combining online and offline teaching and integrating various teaching methods and means, the teaching quality can be improved.

2.2 Implementing Key Steps

Set Up the Curriculum Team. The 1 + 1 + N curriculum team construction mode is adopted, that is, one curriculum construction team is set up for each co-build and shared curriculum, which is led by one university and participated by N universities. The leading university recommends a course president, and other participating universities arrange 1 or 2 teachers to participate. Finally, forming a co-construction mode in which each course is in the charge of one university and about 5 or 8 teachers from three to five universities. In principle, each university is responsible for only one course and participates in many others courses. In this way, among the multiple courses jointly built at the same time, each university only needs to take charge of one advantageous course and provide about the teachers needed for one course, so that it can build multiple course resources suitable for itself.

Determine the Course Co-construction Content Set. The colleges and universities participating in the construction of curriculum resources make curriculum content outline through cooperation. Firstly, the colleges and universities participating in the joint construction have put forward syllabus that meets the teaching objectives and content requirements of the university. Secondly, the syllabus is formed by selecting the Union (maximum) of the syllabus contents of each university. In addition, according to the logical relationship between the curriculum knowledge points, the content is divided into several modules to form a modular curriculum outline. Then, take the intersection (minimum) of the curriculum contents of each university to form the corresponding core module set of the curriculum. Finally, the part of union and intersection difference is also divided into several modules according to its internal logical relationship to form an extension module, as shown in Fig. 2. The core module set and extension module are jointly completed by the participating universities, which also provides the possibility for the later credit certification of the participating universities.

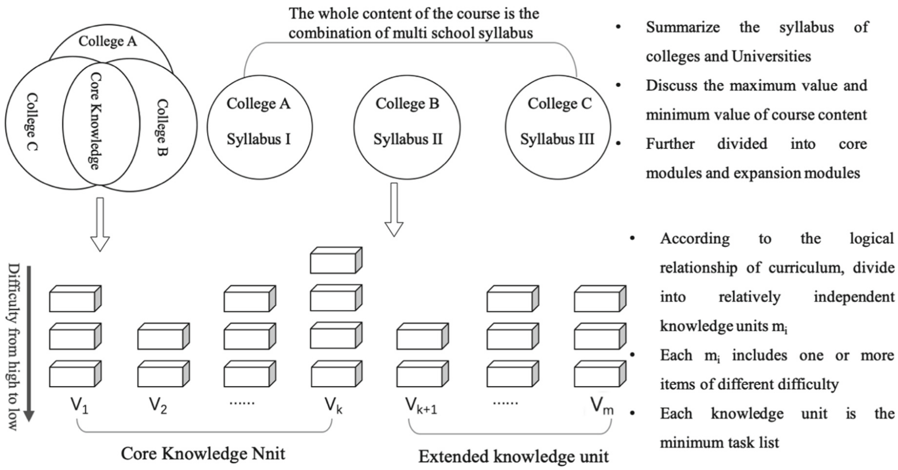

Fig. 2. The Co-Construction of Course Content Set.

Limited Crowdsourcing and Co-construction of Curriculum Resources. Discuss the assignment and implementation of curriculum construction tasks according to the curriculum outline. Universities are only required to complete "limited" tasks, such as the construction of learning resources and implementation plans for one or several chapters of the curriculum. Learning resources include: making teaching videos of course content corresponding to the course module, supporting in-class tests, chapter tests, experimental project library, homework, Q&A videos and other auxiliary materials. The course implementation plan includes: course progress, arrangement of online and offline learning activities (classroom teaching, experimental teaching, etc.), homework submission (classroom homework, experimental homework, etc.), scoring rules and performance evaluation, etc. In addition, it also includes the classroom teaching plan template based on a mixture of multiple teaching methods, which can be used by teachers to select the teaching plan template according to the diverse teaching situations, and carry out teaching design according to the teaching requirements and students' learning characteristics.

Clarify the norms for the construction of curriculum resources. The construction quality of curriculum resources can refer to relevant MOOC construction standards. In the process of curriculum resource construction, the unified style of curriculum resource construction is also emphasized. For example, the shooting of course videos has unified requirements for teachers' clothing and explanations, and the words "Anhui University Course Co construction and Sharing Series – Computer Network" are uniformly marked at the beginning and end of the video. The names and logos of each university are displayed in the order of the leading and participating universities. In addition, in the process of resource construction, it is necessary to fully consider the characteristics of application-oriented undergraduate universities, design targeted teaching courseware, experimental projects, exercise questions, test questions, and provide corresponding reference templates.

Exclusive Sharing of Course Resources on Demand. It will adopt the sharing and sharing mechanism of virtual exclusive curriculum resources.Firstly,complete the construction of curriculum resources and publish them to the learning platform.Then,according to the curriculum implementation plan, set up the curriculum resource organization, learning activities and scoring standards, etc. Such a curriculum covering all the contents of the curriculum is called “Complete Course”. “Complete Course” can be set as public access, private courses or non-public, and can be shared by copying (respective course mode) or referencing (cooperative course mode).

The copying mode means to copy the “Complete course” as “School-based curriculum”. Colleges and universities can appropriately delete the resource modules in the “Complete Course” according to the teaching syllabus of professional courses. Of course, it can also quickly build personalized online courses that are consistent with the school’s talent cultivation goals and curriculum syllabus. The referencing mode means that the leading university and several partcipating universities agree to set up courses at the same time, and the course learning progress and scoring standards are the same. Firstly,the leading university sets the “Complete Course” as “Shared Course”, and other universities directly quote the course to the learning platform of the university. Students access the course from the domain name of the university. Teachers only need to manage the students’ grades and homework, but they can see the learning situation of all college students. Of course, the students can also see their own ranking in the university and all students. All teachers and students discuss and answer questions together. Therefore, this method is conducive to the joint learning and competition of students from multiple schools.

Support Co-construction and Sharing of Learning Management Platform. The learning management platform (TronClass platform [6], which has been used in many universities) supporting the co-construction and sharing of curriculum resources not only contains learning management functions common to online teaching platforms, but also provides supporting functions such as discussion area, homework and test, scoring standard and so on. In addition, it also supports the automatic import of course syllabus, docking with the educational administration system, convenient recording of micro courses, etc. Moreover, it can intuitively display the analysis of students’ academic performance. The biggest feature of the platform is to provide virtual exclusive sharing function, that is, to provide relatively independent cyberspace and platform interface for different universities through multiple domain names and templates. For example, the learning platform of university A can access the domain name: "mooc.a.edu.cn", and the learning platform of university B can access the domain name: “mooc.b.edu.cn”. Then, the multi-template system makes it possible for different universities to select platform templates suitable for their own characteristics. The colleges and universities can also customize personalized teaching resources according to the actual teaching needs of the university and publish them with the independent domain name of the university. Later teaching activities are carried out in an independent space, including classroom management, student management and achievement management. In addition, the platform also supports course duplication and reference, as well as cooperative course opening and class management among colleges and universities, as shown in Fig. 3.

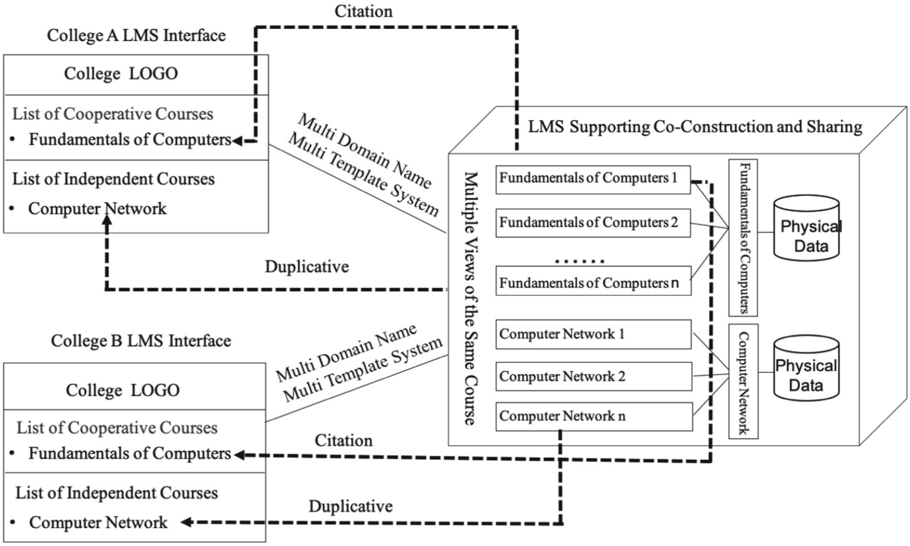

Fig. 3. A Learning Platform Supporting Co-Construction and Sharing of Courses.

Establish a Long-term and Effective Feedback Mechanism. On the one hand, curriculum sharing universities are required to carry out questionnaires at the beginning and end of each semester to collect data on students' learning status in a timely manner, organize and analyze the questionnaires, summarize existing problems and shortcomings, and make targeted improvements and optimization. On the other hand, teachers are required to write a teaching design plan before conducting teaching, detailing the methods of online teaching activities and performance evaluation methods, as well as the development methods of theoretical and practical courses. After the completion of the course, students' learning process data should be promptly collated, the effectiveness and shortcomings of the course implementation should be analyzed, and continuous optimization and improvement should be made.

2.3 The Features of the Mode

Respect the Needs of Co-constructing Universities. Each university leads the construction of a course and arranges relevant teachers to participate in the courses led by other universities, ultimately forming an equal and cooperative situation where each course is jointly constructed by multiple universities and each university hosts the course. During the course resource co construction stage, as the co construction course outline covers the needs of all colleges and universities, and is based on the minimum knowledge unit of knowledge points to produce resources such as videos, each college can freely increase or decrease in the later stage to adapt to actual needs; In the sharing stage, universities can freely set the content, progress, form, etc. of course resources according to their actual needs to meet their personalized needs.

Provide the Possibility for Credit Mutual Recognition. Traditional credit mutual recognition requires colleges and universities to be able to recognize the achievements of their students' studies outside of school, but it has certain difficulties. The course co construction and sharing mode proposed in this paper is that each university learns on the same platform, but the learning platform provides independent interfaces for different schools through a multi domain name system, namely a virtual exclusive online teaching management platform. Each university shares and organizes online courses that meet its own characteristics according to actual needs. The platform is accessed through the university's domain name, the courses are also built by the university itself, and the learning process is also managed by the university's teachers. Therefore, there is no problem of credit mutual recognition. This sharing method based on curriculum co construction avoids the traditional idea of credit mutual recognition and provides the possibility for credit mutual recognition.

3 Model Application and Effectiveness

3.1 The Mode Application

In 2017, Anhui Education and Scientific Research Computer Network established the first information technology and teaching integration working group in Anhui Province [7].The group leader is located in Chuzhou University. The group leader sets the standards of co-construction and sharing of curriculum resources and develops the co-construction and sharing learning platform of curriculum. The first batch of four application-oriented colleges and universities in the province were selected, namely Chuzhou University, West Anhui University, Huaibei Normal University and Suzhou University. Then, the four undergraduate majors of wireless sensor network, computer network, C language programming, microcomputer principle and interface technology were started to carry out the co construction and sharing of curriculum resources. As shown in Table 1, it is mainly divided into two stages: co-construction and sharing of curriculum resources.

Table 1. The Basic Information of Co-Construction of the First Four Courses.

Course Name	Leading Universities	Participating Universities	Number of Co-Constructed teachers
Wireless Sensor Network	Chuzhou University	Taiwan Tamkang University、West Anhui University、Suzhou University、Huaibei Normal University	6
Computer Network	West Anhui University	Chuzhou University、Huangshan University、Chizhou University	8
Microcomputer Principles and Interfacing	Suzhou University	Chuzhou University、Chizhou University	6
C language programming	Huaibei Normal University	Chuzhou University、West Anhui University、Suzhou University、Anhui University of Architecture	8

The Co-Construction Phase. Firstly, the four inter university cooperative curriculum construction teams were set up to identify the leading universities, participating universities, co-construction teachers and curriculum principals. At the same time, more than

10 universities in the province were selected to cooperate with the leading universities to jointly complete the curriculum co-construction work. Secondly, the co-construction of colleges and universities made the curriculum outline through consultation, and generated the maximum set and minimum set of curriculum content through discussion, and formed the core module and extension module. Then complete the co-construction of curriculum resources, including the construction of curriculum videos and various teaching supporting materials, etc. Taking the course of Microcomputer Principle and Interface Technology as an example, as shown in Table 2. Finally, the test goes online and provides a variety of use templates for teachers and students to choose.

Table 2. The Curriculum Resources Construction of Microcomputer Principles and Interfacing as an example.

Chapter Name	Data Name	Video	Completion
Chapter 1 Proteus ISIS Introduction		Video	60 (Average Duration 11 Minutes)
Chapter 2 8086 CPU		Courseware	16
Chapter 3 Assembly language programming		Experiment	17
Chapter 4 Memory	Curriculum Resources	Task	13
Chapter 5 Programmable Counter / Timer 8253		Question Bank	200
Chapter 6 Programmable parallel interface chip 8255		Discuss	16
Chapter 7 Programmable interrupt controller 8259		Supplementary Resources	113
Chapter 8 Programmable serial communication interface chip 8251	Syllabus	/	Complete
Chapter 9 Digital to analog(D/A)and analog-to-digital (A/D)conversion	Teaching Plan	/	Complete
Appendix 8086 common assembly instructions and pseudo instructions	Curriculum Reform Implementation Plan	/	Complete

The Sharing Phase. Relying on the course co-construction and sharing learning platform TronClass, we carried out the practice teaching reform of on-demand exclusive sharing of course resources in 16 application-oriented colleges and universities in Anhui province. Due to the build phase of the construction of the syllabus covers all participate in colleges and universities needs, and according to the knowledge production fragmentation teaching video. Therefore, the colleges and universities can freely allocate the content, progress, organization form and grade evaluation of the curriculum resources according to the universities' training objectives, so as to realize the sharing of curriculum resources and ensure the personalized needs of each university. In addition, the course has an independent domain name and independent space, each university can choose to run the course at the same time or independently according to their needs.

3.2 The Effectiveness of Model Implementation

Based on the limited crowdsourcing and exclusive on-demand sharing mode of curriculum resources, it has been implemented for 5 years since 2017, and has achieved a series of achievements. During the period, more than 20 seminars on jointly constructing and sharing courses have been held [8–12]. Nearly 30 lectures have been delivered at domestic and foreign academic conferences and teaching conferences. The specific results are mainly reflected in the following four aspects:

This Model Provides Demonstration and Guidance for the Teaching Reform in Colleges and Universities. Based on this model, nearly 30 provincial first-class courses, CMOOC alliance construction courses or excellent courses and hybrid teaching reform projects have been built in Colleges and universities [13]. The textbooks jointly constructed and compiled have been selected by 8 courses in 10 universities, benefiting more than 50000 students. The monograph "MOOC and mixed teaching theory and practice" was published and distributed to more than 20 provinces in China, with a volume of nearly 10000 copies, which is called the most closely integrated theory and application monograph. The related papers have won the first prize in the National Computer Education Conference for many times, and have made great repercussions. The research and practice of first-class course construction based on "limited crowd-sourcing co-construction and On-demand exclusive sharing" won the special prize of Teaching achievement in Anhui Province.

This Model Effectively Promotes the Professional Construction and Talent Training of Co-built Universities. Based on the support of this model, the co-construction universities have made remarkable progress in the professional reform, construction and talent training. There are 12 major approved as provincial-level first-class (brand) or characteristic majors, and 4 computer majors have been approved as the national first-class undergraduate majors. According to incomplete statistics, more than 400 students of computer majors in co-construction universities have won more than 100 prizes in various competitions every year.

This Mode Effectively Improves Students' Learning Enthusiasm and Learning Effect. A questionnaire survey of more than 1,000 randomly selected students for five consecutive years from 2017 to 2021 shows that the number of students who think their learning effect is better or significantly better is basically increasing year by year. The satisfaction with the mixed learning method of MOOC based on limited crowdsourcing and on-demand exclusive increased from 59% in 2017 to 79.92% in 2021, while those who believe that teaching quality and learning effect are similar decreased from 38.5% in 2017 to 18.66% in 2021, as shown in Fig. 4. The above data show that this mode effectively promotes students' enthusiasm for learning and their ability and awareness of autonomous learning based on MOOCs.

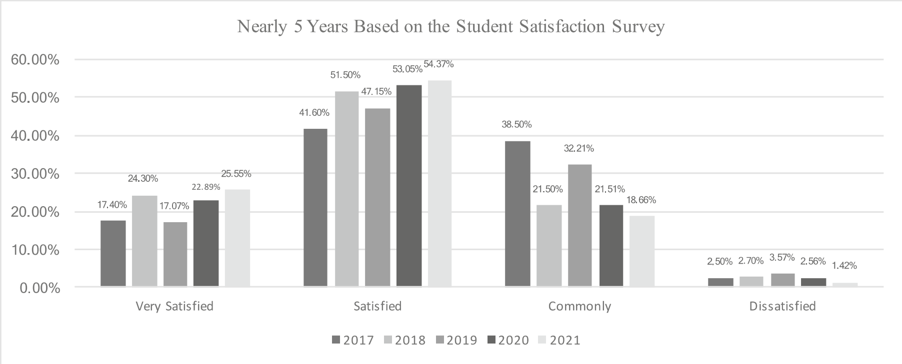

Fig. 4. The Statistics of beneficiary student satisfaction survey based on this model.

This Model has Effectively Trained a Number of High-Level Teachers. Based on this model, a group of teachers with high-quality teaching, scientific research and teaching research ability have been trained to lead the teaching reform and first-class curriculum construction of the university. Among the co-construction universities, one person is appointed as a member of the Computer Course Teaching Steering Committee of the Ministry of Education, seven people are awarded as provincial Famous Teachers, three studios of famous teachers, three virtual teaching and research rooms, and four person are executive members of CCF Education Committee.

According to the questionnaire survey of nearly 100 teachers randomly selected from application-oriented universities in Anhui province.84.14% of teachers agree with the limited crowdsourcing and on-demand exclusive course resource co-construction and sharing mode. 98.07% of teachers believe that the participation in course co-construction and sharing is helpful to the improvement of teaching ability. 96.34% of teachers believe that the course co-construction and sharing mechanism is helpful to promote the construction of first-class courses in application-oriented universities, and 98.08% of teachers are willing to continue to participate in the co-construction and sharing of course resources in the future, as shown in Fig. 5.

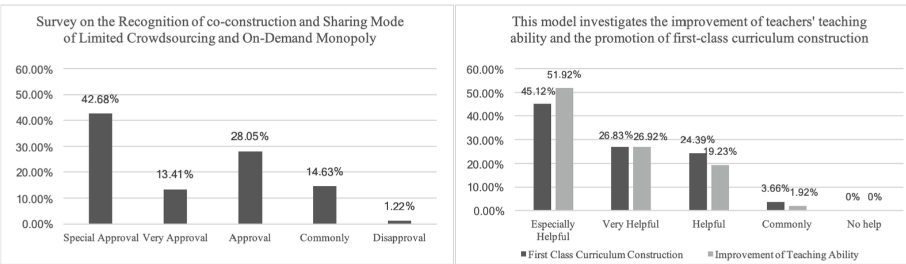

Fig. 5. The Statistics of teacher satisfaction survey based on this model.

4 Summary

The model of co-construction and sharing of curriculum resources based on limited crowdsourcing and on-demand exclusiveness proposed in this paper has been promoted to more than 20 colleges and universities in and outside the province, which has effectively promoted the teaching reform of colleges and universities, and improved the quality of curriculum, specialty construction and talent cultivation. At the same time, we have achieved a series of achievements and won some high-level awards. These achievements have a certain significance for the application-oriented universities to carry out the first-class curriculum construction. In the future, we will focus on the automatic evaluation and review of the quality of curriculum content, cases and projects, automatic collection and evaluation of data in the process of students' learning, cross school elective, data sharing and credit recognition, etc., so as to promote more universities to provide the teaching level and talent training quality.

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Experience Report on Innovative Experiments for Compiler Course

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Abstract. After five years of teaching of the Compiler Principle and Technology course, we realized that the conventional experiment setups had been lagging behind the fast evolution of modern compilers, and thus cannot fulfill the teaching objectives of helping students get trained for future practice in the related fields. To close the gap, the teaching group has designed a series of innovative experiments, which incorporate the advanced compilation techniques such as LLVM, RISC-V, etc., and follow four tracks, namely, the generation of back-end code, advanced optimizations of intermediate representation, extension of language features, and error diagnoses. To assess students' creativity, we only give a minimum set of information, and expect students to find their own solutions. We deployed the innovative experiments in the fall semester of 2021, which were optional and complemented to the mandatory experiments. Our major findings are (1) though many students were interested in, only a small group of students submitted their projects; (2) more than half of participants delivered solutions much better than our expectation, and received high scores; and (3) the submitted projects revealed that students already knew how to apply the principles and techniques taught at class to their practice.

Keywords: compilation principle · innovative experiment · advanced optimization · error diagnostics

1 Introduction

The training goals of the major of computer science (CS) in the new computing era are materialized as "computational thinking", "system ability", "innovation ability" and "engineering practice ability". Among them, "system capability" refers to the ability to understand the integrity, relevance, hierarchy, dynamics and openness of computer systems, to understand the cooperation and interaction between computer hardware and software, and to comprehensively use a variety of knowledge and technologies to develop systems. The "Compiler Principles and Techniques" course (or short, compiler) is one of the core courses in the curriculum of the CS major to help college students build their system capabilities [1].

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Compilation technology is one of the earliest major fields of system programming, which involves knowledge in many fields such as formal languages, high-level language programming, data structures and algorithms, computer architecture, operating systems, and software engineering [2]. Compilation principle introduces the theory, method and technology of compiler construction, and undertakes the task of cultivating reserve talents for the construction of independently controllable chip ecological environment [3]. The goal of the course "Compilation Principles and Techniques" is not only to give students a deep understanding of the design and implementation technology of programming languages, but also let students initially accumulate software development experience and the ability to apply the concepts and techniques discussed in the course to software design and development and scientific research.

Practical teaching is the testbed for classroom theoretical teaching. Appropriate practical teaching can significantly enhance students' innovative ability. Practical teaching is the best carrier for "two characteristics and one degree" [4,5], and also is an important part of the construction of "golden courses". Therefore, the practical teaching plays a key role in the compiling courses. The main teaching objectives of the practical teaching of compilation principles are as follows.

- Cultivating students' ability to combine theory with practice.
  Through the practice, students need to understand the composition of a compiler and the functions of its various subsystems, know the basic theory required to construct each subsystem, and master the formal method to describe the language.
- Improving students' system design capabilities.
  Students should master the key techniques of language processing and translation of compilation theory while enhancing the ability to design and analyze complex systems in the future.
- Developing students' ability to implement complex software systems.
  Basic methods of data structure and algorithm design, modularity and coordination and code organization should be mastered by the students. In addition, students should get the hang of the typical programming methods such as top-down and bottom-up designing approaches, recursion strategies, etc. to develop the ability to implement complex software systems.
- Cultivating students' innovative ability.
  Introducing emerging technologies that are innovating and evolving in practical teaching is an important supplement to classroom theoretical teaching. Learning the innovative development tools and mastering the cool innovative technologies can further stimulate students' enthusiasm for learning and the cultivation of innovative ability.
- Cultivating students' expression skills.
  Students should improve the key expression skills from summarizing reports for the experiments, clarifying about problem definitions and presenting their own solutions to teachers and other students.

In the practice of compiling teaching, the teaching group found that the conventional experimental scheme is not difficult enough and seriously outdated, which is not conducive to the cultivation of students' system capability and innovative spirit. The teaching group designed a series of innovative experiments and carried out teaching practice, and finally achieved good results.

2 Problems and Solutions Found in Compilation Practice Teaching

In the process of compiling practice education, the teaching group found that the traditional compiling practice teaching could not complete the teaching objectives of the course, and the following problems existed.

- The traditional experimental difficulty is not enough.
  In order to take care of students with the average level, the traditional experimental difficulty is not enough, resulting in insufficient training of some outstanding students. The traditional compilation experiments are mostly small verification experiments, and students carry out the implementation of experiments based on the knowledge points learned in classroom teaching [6]. This kind of compilation experiment includes lexical analyzer implementation and syntax analyzer implementation, etc. For example, given a tiny language containing only a few keywords, students are required to design corresponding lexical analyzers, so that the lexical analyzers can identify keywords; syntax analyzers (analyzers such as LL and LR) can analyze sentence structure. However, this type of experiment is not difficult enough. For students with better ability, they need more difficult experimental subjects for thinking and exploring.
- The traditional experimental content is out of date.
  The traditional experimental content cannot reflect the development direction of compilation technology. The traditional compilation experiment focuses on the front-end and covers minimal content of the back-end, which cannot reflect the complexity of the compiler and also the state-of-the-art industrial issues. This type of experiment is not guaranteed in terms of engineering complexity and challenge, resulting in insufficient training of students' system ability. In the current new computing era with the rapid development of heterogeneous hardware (multi-core, GPU, FPGA, RDMA, etc.), the experimental content of the school should also keep pace with the times and reflect the development characteristics of the times. In terms of compilation practice design, more emphasis should be placed on intermediate representation optimization and back-end implementation.

In order to solve the above problems, the teaching group has designed the following solutions.

- Multi-level experimental projects.

The overall experiments are divided into mandatory part and innovative part. The former includes implementation of parser, intermediate representation code generator and simple code optimization. By completing the mandatory experiments, students can consolidate the knowledge learned in the classroom and have a preliminary understanding of the development direction of compilation. The innovative experiments are designed for the students who enjoy learning and exploring more contents and have spare capacity to practice. Innovative experiments have a certain degree of engineering difficulty, and the high engineering threshold is likely to make average students feel intimidated and weaken the average students' interest in learning and enthusiasm for practice. In order not to affect average students, students can choose whether to complete innovative experiments according to their own abilities. Incentive mechanisms such as extra grade points are used to encourage students with better grades to complete innovative experiments. Through this layered design, students can be taught in accordance with their abilities, and students' potential can be tapped to avoid the phenomenon that some students can't enjoy enough, and some students can't complete the experiments.

– Innovative experiments of optimization and extension.
  The innovative experiments are designed to closely follow the current development direction of the compiler, compress the outdated content which used in the previous experimental scheme, and focus on strengthening the intermediate representation optimization and back-end design of the compiler. In the course of the innovative experiment, only the agreement of the research direction is carried out, and there are no too many restrictions. Students are free to play and explore. Allowed to find and solve problems by themselves, students are more possible to get interest in scientific research.

3 Innovative Experiment Design

The teaching group divided the experiments into basic experiments and innovative experiments, of which there were five basic experiments and one innovative experiment. The steps of compiler experiment are divided into six interlocking experimental projects, from easy to difficult, theory combined with practice, so that students have a clearer and deeper understanding of the theoretical knowledge of the textbook, and also improve their hands-on ability, analysis ability and solving ability through practical operation. At the same time, through the setting of related experimentals, the teaching group strive to let students gain certain experience in modern compilation technology. The overall experimental architecture is shown in Fig. 1. All experiments target Cminus-f language, which adds float support to a classic teaching programming language Cminus.

In our base experiments(Lab0~4), students build a Cminus-f compiler that can translate cminus-f codes into LLVM IR-like intermediate representation. To further exploit students' creativity, we design innovative experiment that requires extensive research and lots of hard work. We define multiple tracks with optional requirements in innovative experiment rather than detailed description. Therefore, they need to define their own problems, and give solutions.

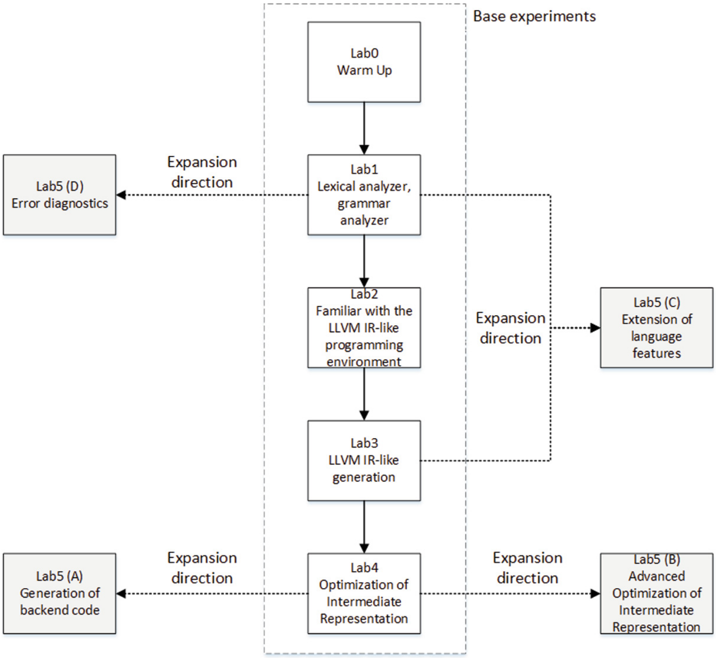

Fig. 1. The overall experimental architecture.

3.1 Generation of Backend Code

This track requires students to implement a code generation module to translate intermediate representation to the backend codes. They can choose their most familiar backend platforms (such as x86, arm, RiscV, cpu0 [7]) for this experiment. Additionally, they need to prove the correctness of generated codes with a simulator(or genuine CPU) and runnable examples. Students can refer to existing projects (e.g. LLVM [8]) for technical challenges and possible designs. The most difficult part in this track is to complete the translation of the phi instruction.

3.2 Advanced Optimization of Intermediate Representation

In the base experiments, students have been asked to implement constant propagation, dead code elimination, loop invariant extraction, and active variable analysis. This track requires the implementation of more complex and advanced optimization passes, such as SCCP Combined DCE, GVN, GCM, or optimization passes with similar complexity. The implementation difficulty, optimization effect and code integrity of the pass will be comprehensively considered in evaluation.

3.3 Extension of Language Features

This track requires students to extend the Cminus-f language with more complex and useful language features. These features can be pointers, multi-dimensional arrays, or structures. Any features from different languages (or even their new invention) are welcomed as long as they can adapt them into cminus-f and provide correct implementation of parsing and compiling.

3.4 Error Diagnostics

Base experiments assume all input files are well-formed and correct cminus-f program. But real compiler has to face ill-formed or buggy program, and gives detailed diagnostic information such as error location, error reason, code context. This track requires students to add the ability to handle error and give diagnostic information to cminus-f compiler. They can choose to support different kinds of errors, including syntax error, semantic error, uninitialized access error or even boundary check for array accesses. They can refer to the error recovery chapter of the Bison Handbook [9].

4 Innovative Experiment Organization and Assessment Methods

We publish information of the innovative experiment on the course Gitlab website, and students can choose whether or not to participate in it. We give one month for completing the experiment. Students are encouraged to post questions and insights on the course Gitlab website, teachers and teaching assistants to follow the questions and discussions on the GitLab website, and eliminate students' confusion through timely and multi-topic parallel online Q&A. This kind of course experimental tutoring design has been widely praised by students who choose the innovative experiment.

The total score of the innovative experiment is 5 points, which is directly added to the final score of this course. It will be given based on the completeness of their implementation and their open reports. Students are asked to make a public report and answer the questions from a jury consisting of teachers and teaching assistants. And then, teacher assistants assess the submissions by manually confirming the effectiveness of the implementation and judge the completeness.

5 Experiment Effect Analyses

In the fall semester of 2021, there are a total of 140 students participating in the compiler Principles class, and 42 of them signed up for innovative experiment. At the end of the experiment, 12 students chose to submit the innovation experiment for reporting. The experiment completion rate is 28.6%. The low completion rate also indicated that this innovation experiment is difficult. From Fig. 2, it can be seen that 6 students completed track A; 1 student completed track B; 5 students completed track C. The distribution of experiment scores is shown in Fig. 3, and the average score of each track is shown in Fig. 4. The teaching group found that students are more willing to complete open-ended challenges (such as track A and C). Further expanding the openness of the experiment in the subsequent teaching practice will be the follow-up improvement direction of this experiment.

The teaching group conducts a special analysis on the students who have completed the innovative experiment. The average final score of the students participating in the innovative experiment is 91.6 points, which is higher than the class average score of 78.8 points, as shown in Fig. 5. From Fig. 5, it can be seen that the overall level of the students who completed the innovative experiment is at the forefront of the class. This further reflects the high-level challenges in this innovative experiment.

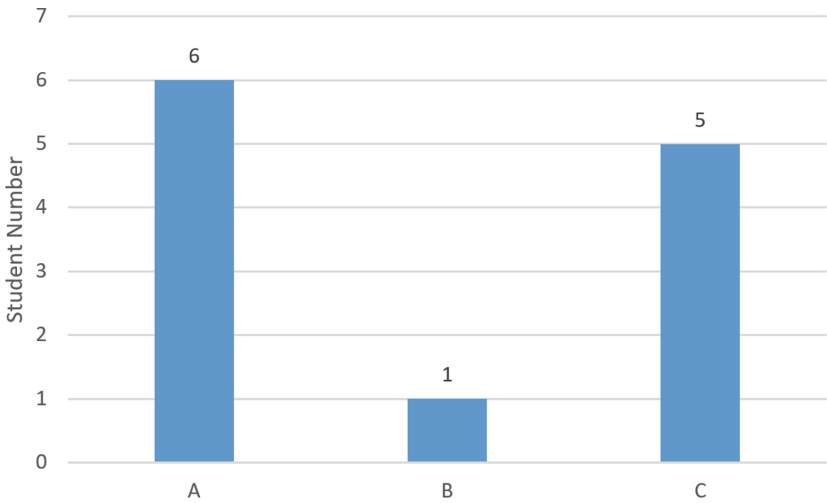

Fig. 2. Distribution chart of students' experimental topic.

During the experiment, the student git repositories were actively updated, and an example of the student's git submission history is shown in Fig. 6. The total number of submissions for the innovative experiment is 1513, and the average number of submissions per student is 126.1. The relationship between students' final experimental scores and the number of submissions is shown in Fig. 7. As can be seen from Fig. 7, the students who completed the innovative experiment all made considerable efforts.

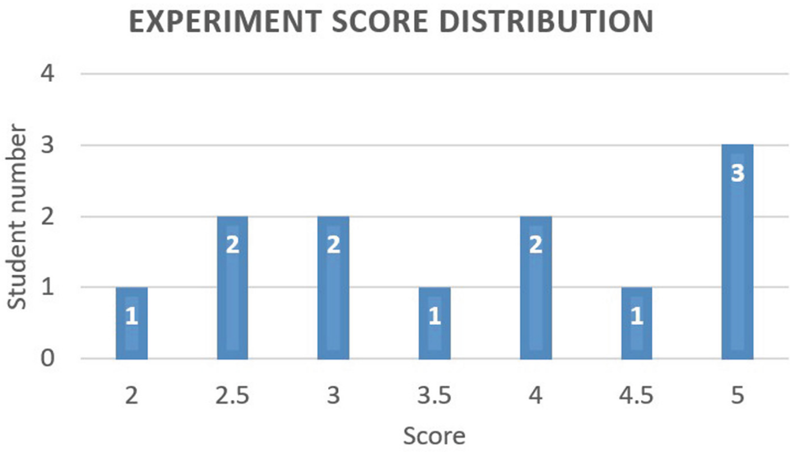

Fig. 3. The distribution chart of students' experimental score.

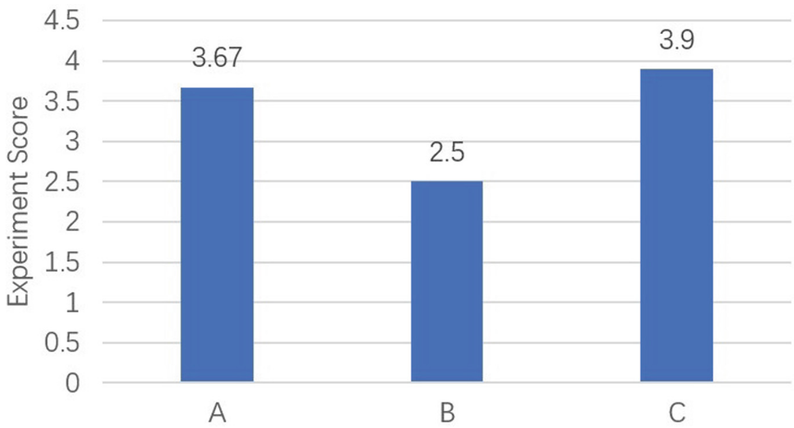

Fig. 4. The average score distribution for each track.

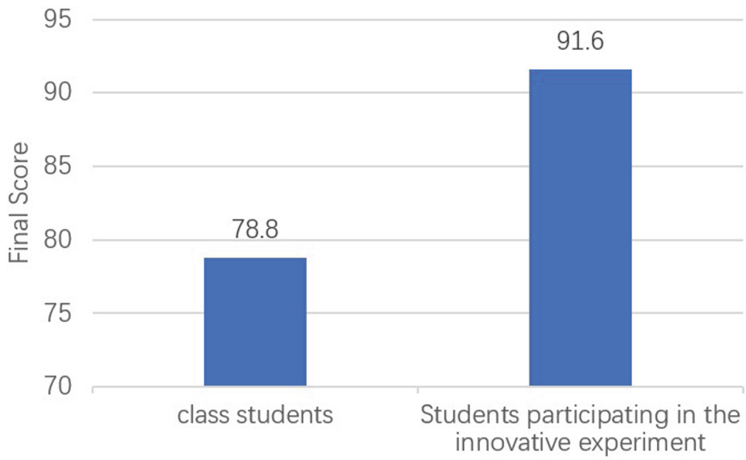

Fig. 5. Students total score comparison.

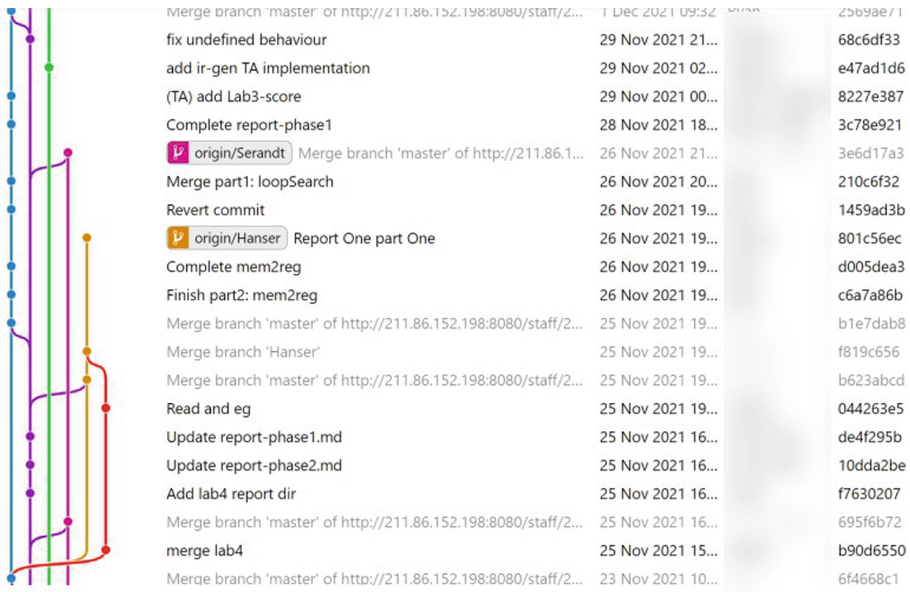

Fig. 6. Example of a student's GIT commit history.

Analyze the effect of students' implementation. Taking a student who chose track C as an example, the new language features implemented by the student in the experiment are as follows.

– Type extension
  Completed statement analysis and code implementation of pointers, high-dimensional arrays, and structures. It specifically solves the lexical and syntax

analysis of complex grammars such as null pointers, array pointers, pointer arrays, and structures, and realizes the translation and understanding of high-level statements like *int *((*p[10])[10][20])*.

- Variable initialization
  Complete the initialization of local variables, global variables, and structure members. For structs and arrays, an example of initialization of such a complex structure is as follows:
  struct A { int a; float b; };
  struct A t[2] = { {1, 2.0}, {3} };
  For the initialization of global variables, refer to the translation process of *clang*, put the initialization of each global variable in the initialization function, and the initialization function of the program is called before the main function to complete the initialization of global variables.
- Function overloading
  When looking for a function, look up from the scope, function name and whether the function parameters match.
- Implement C++ object-oriented functions
  Specifically, including member functions and class inheritance. The implementation is designed with reference to the translation process of *clang*, that is, if B inherits from A, set the position of the first element of type B to type A.

An example of new language feature implemented by this student is shown in the Fig. 8. This experiment effect greatly exceeds the expectations of the teaching group, and the jury agreed to give full marks. The video of all students making reports of the innovative experiment has been published on the bilibili website (https://www.bilibili.com/video/BV1oR4y1G72s), as shown in Fig. 9.

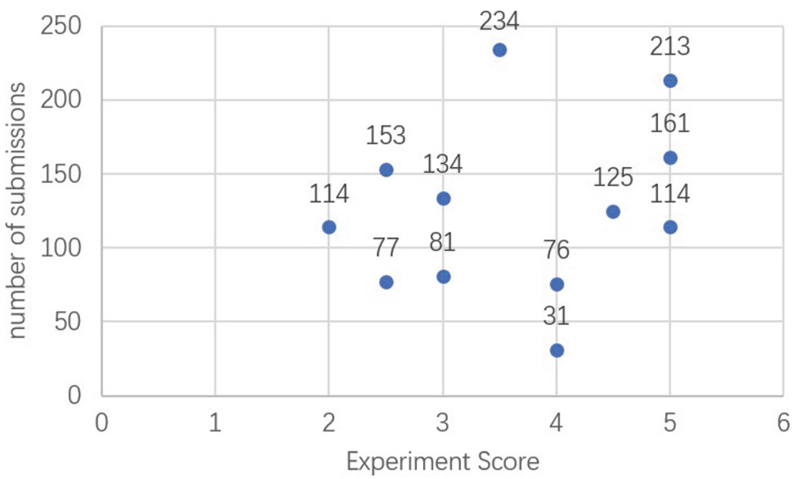

Fig. 7. The relationship between students' experimental scores and the number of git submissions.

```
struct A
{
    int a = 2;
    int b = 1;
    int test(void)
    {
        return a + b;
    }
    int test(int i)
    {
        return i;
    }
};
struct B : A
{
    int c;
    int test(void)
    {
        return c + a;
    }
};
```

```
int main(void)
{
    struct B *b = new {5};
    struct A *a = b;
    output(b->c);
    output(b->a);
    output(b->b);
    output(b->test());
    output(a->test());
    output(b->test(99));
    return 0;
}
```

```
output :
5
2
1
7
3
99
```

Fig. 8. Example of student implementing language features.

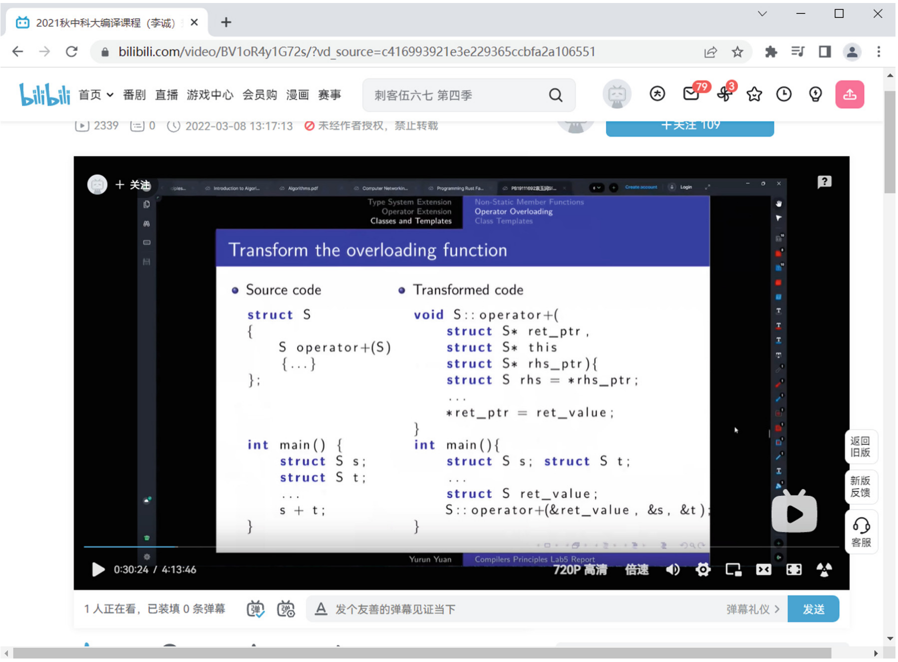

Fig. 9. Screenshot of the student's report video.

6 Conclusion

In order to meet the differentiated needs of students, optional innovative experiments are introduced in the compiler principle class. A relatively complete innovative experimental scheme is formed. Using the innovative experimental program, students can learn and master advanced compilation technology, understand the development direction of compilers, cultivate students' ability to investigate and master new development tools, and stimulate students' enthusiasm for learning and innovative ability development. During the experiment, students need to master software engineering methods and tools(such as Git version management, build tools make or cmake, Internet code repository GitHub and document repository GitBook and other sharing and collaboration tools), as well as new features and programming in C/C++ languages. Through the exercise of innovative practice, students can cultivate their programming practice ability, organization and management of multi-file software projects, and software engineering capabilities such as version management. Through teaching practice, innovative experiment practice have achieved good teaching results. The teaching group has shared the relevant report video and other materials on the Internet to facilitate the reference and communication of teachers in need.

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Learning Styles Identification Model in a MOOC Learning Environment

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Abstract. Different online learners have different learning styles that are influenced by their prior knowledge and personalities, which necessitates the use of an online platform to identify these learning behaviors in order to enhance the course. Based on the Felder-Silverman model, we offer a novel learning style theory model suitable for MOOC education environments in this work. Then we extract high-dimensional features from the MOOCCube data set produced from China's XuetangX platform. Furthermore, to identify online users' learning styles, we apply a two-level hierarchical learning style classification model. First, a learning autonomy classification model is used to filter inactive learners by collecting the learner autonomy index from the data set. Then, to detect distinct learning styles, we construct a clustering-based behavior identification model using the Gaussian Mixture Model. Our hierarchical classification model demonstrates great capability and enables researchers to conduct analytical studies on the learning patterns of online learners.

Keywords: Online Learning · MOOC · Learning Style Model · Learning Autonomy

1 Introduction

Massive Open Online Courses (MOOCs) rapidly change modern learning methodologies and platforms, driving the traditional teaching scenario's evolution into a virtual, mobile, and data-driven environment. MOOC is an open and flexible online course that allows for limitless participation and open Internet access. This novel approach allows a large number of students to engage in digital learning with professors and teaching assistants from all over the world.

However, because of the massive and open access characteristics, various learners with distinct learning styles may encounter challenges under this unified and standard online learning strategy. To address these problems, a conceptual model and further data analysis on online learning behavior become critical. The Felder-Silverman model [13], with four dimensions and 16 kinds spanning perception, input, processing, and comprehension, is the most extensively used learning style model for describing online learner behaviour. It provides the theoretical foundation for online learning style classification, and many studies use classification algorithms based on the assumption of the Felder-Silverman model.

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https://doi.org/10.1007/978-981-99-2446-2_22

One strategy is to use information from learners' subjective cognition of their learning style to generate the training data set by assigning massive questionnaires [7]. Further supervised machine learning algorithms are applied to the data set and finally it constructs a learning style classification model. Such a questionnaire-based strategy generally requires time-consuming data collecting and runs into the issue of limitation of learners' self-awareness on their own learning style. Furthermore, other researchers will find it difficult to compare the results and undertake online learning behavior analysis on a larger scale using the closed-source data set.

The other approach is to classify learning style based on clustering-based unsupervised algorithm. Several studies utilize the learner behavior directly as the classifier's input and implement clustering algorithm such as K-means to divide the learners into several groups [11]. However, it is prone to including superfluous user behaviors such as dropping out of an online course or being insufficiently self-motivated into the classification model. In this traditional technique, inactive learners cannot be identified using the learning style model, and they may be assigned the incorrect learning style as a result of their lack of learning autonomy and engagement over a long period of time.

To solve the challenges in the learning style classification, we analyze the user behaviors on XuetangX MOOC platform in China and propose a modified learning style model that improves the dimension and category design based on Felder-Silverman's. Our hierarchical model consists of the front-end Learning Autonomy Classification Model and the back-end Clustering-based Behavior Identification Model.

We propose a learning autonomy classification model based on user activities over several weeks to determine whether they are actively interacting in the online course and, lastly, to tag the active learners with their active levels. These high dimensional behavior features and active level vectors and are used to train and choose the best supervised machine learning model.

Following the filtering of inactive learners, we use Principle Component Analysis (PCA) to reduce the high-dimension behavior features to two dimensions in order to improve the effectiveness of subsequent clustering techniques. Then, using the PCA result, we apply a Gaussian Mixture Model to classify online learners into the dimensions and kinds specified in our modified learning style model for MOOC learners.

2 Related Work

2.1 Learning Style Theory

Research on Learning Style Theory is closely related to "Student Centered" teaching method, which is also described as "Teaching Students in Accordance with Their Aptitude". "Learning Style" was defined by Herbert Thelen as a new concept in the field of education. After a long history of research, several learning style models are mature and well adopted. Currry's learning style model [12] divides all learning styles into three levels, "teacher preference", "information processing mode" and "cognitive style". Felder designed the Solomon learning style model for measuring learning styles [13]. Felder-Silverman's model is advantageous in web-based learning environment like MOOC, and is widely-adopted in online learning style research. This model classifies 16 learning styles into 4 dimensions, which are information process, information perception, information input and information understanding.

2.2 Learning Style Classification Algorithm

Recent research on learning style classification can be divided into two categories: literature-based approach and data-driven approach. Literature-based approach applies simple and fixed rule on learner behavior patterns as indicators to predict their learning style. It requires knowledge about the psychology of learning to estimate the importance of the indicators [6]. Data-driven approach uses machine learning algorithm to extract implicit features from the data set. One of the data-driven approach is to design and assign questionnaire to establish the training set of a supervised learning algorithm and then apply the trained model to classify other online learners' style [7]. However, such works highly rely on learners' responses to a questionnaire on different learning dimensions. Such questionnaire-based method is time-consuming, especially when the data set is relatively large, and highly depends on the self-awareness of the learners in answering the questions.

2.3 Online Learning Data Set

A solid and comprehensive data set is the foundation for undertaking data-driven analysis in the field of online learning and computer-assisted education. Several research evaluate online learning patterns using small-scale and closed-source data sets acquired manually from hundreds of users. [1] [2]. Researchers can distribute questionnaires to such small-scale group and obtain the subjective perspective of participants' learning behavior preferences. Such collected questionnaire results can further contribute to supervised model training to improve the classification accuracy.

Other studies focus on the public open online learning platform data set such as OULAD [3] and CAROL [4]. They collect data from several online courses with thousands of learners. However, there is few research discussing the large-scale Chinese learner' behaviors on public online platform for the lack of available open-source data set. Recently, MOOCCube [5] was proposed to provide a large-scale data repository of over 700 MOOC courses, 100k concepts, 8 million student behaviors with an external resource. They preserve the enrollment records and video watch logs of over 190,000 users from 2017 to 2019 on XuetangX, one of the largest MOOC website in China.

3 Methodology

3.1 MOOCCube Data Pre-processing

We extract user traces of 247 cources, 69823 users and 157943 enrollment from 2015 to 2018 on XuetangX platform. The raw data of XuetangX consists of multiple json files describing the course information, user profile, and course click-stream statistics. We convert the whole json format original data set into multi-dimensional input feature map (Table 1).

Table 1. Data Dimension of Learning Behavior Feature

Category	Variable Name	Type	Encoding
video	Seek Video Play Video Pause Video Stop Video	Count Times	Linear Encoder
User Profile	Age Education Gender Username	Number and String	One-hot Encoder
Problem	Assigned Problem Correct Answer Saved Problem Incorrect Answer	Count Number	Linear Encoder
Forum	Create Thread Create Comment Delete Thread Delete Comment	Count Number	Linear Encoder
Interaction	Click Progress Click Wiki Click About Close Homepage	Time Stamp	Linear Encoder

The input behavior data is divided into five categories and provides extensive information on the online learning procedure. Furthermore, such a data set can be effectively analyzed to extract user-level information. Four factors connected to visual video-watching behaviors are originally various discrete time stamps in the course time line in the "Video" category. We count the number of times the behavior occurs and use a linear label encoder to normalize such statistics. The same processing techniques are used in the categories "Problem," "Forum," and "Interaction." To ensure information fidelity, unique discrete labels such as "Education" and "Username" should be encoded in one-hot label, which will not influence different labels' weight representation.

3.2 Modified Learning Style Model for MOOC

Felder-learning Silverman's style hypothesis contains four aspects and categorizes various learning styles into 16 groups. However, not all characteristics in the Felder-Silverman model are well suited to MOOC online learning situations. For example, the information perception dimension separates learners based on whether they solve issues creatively or prefer abstract or specific resources. While practically every learner in a MOOC environment will receive the same basic course materials, it is unlikely that learners will have sufficient degree to chose for themselves. Furthermore, the sequential/global dimension is problematic in the most common MOOC learning pattern. As a result, we concentrate on the current active/reflective and visual/verbal dimensions while introducing a new social/solitary dimension based on the evaluation of interpersonal characteristics from other researchers' practice [7] (Table 2).

Table 2. Mapping of Learning Style Dimension and Learner Behavior

Visual/Verbal	Active/Reflective	Social/Alone
Seek Video	Click Progress	Create Thread
Play Video	Click Wiki	Create Comment
Pause Video	Click About	Delete Thread
Click Wiki	Close Homepage	Delete Comment
Click About	Assigned Problem	
	Correct Answer	

3.3 Hierarchical Learning Style Classification Model

We implemented a two-level hierarchical classification model. The learning autonomy classification model at the front-end captures multidimensional learner features and predicts their learning autonomy index. Low autonomous learners will be identified by the front-end model, and their data will not be passed on to the next phase.

Following the autonomous classification stage, principal component analysis (PCA) was used to reduce the original high-dimensional feature space for each learning style of the processing dimension to a smaller one. The back-end further divides online learners into distinct categories using a clustering method. Using the elbow point approach, we can determine the optimal number of clusters.

Learning Autonomy Classification Model. One possible simple definition for learning autonomy is "the ability to take charge of one's own learning" [8]. Although it might be a controversial term hard to be defined precisely, there is a consensus among the education researchers that the practice of learner autonomy requires insight, a positive attitude, a capacity for reflection, and a readiness to be proactive in self-management and in interaction with others [9] (Fig. 1).

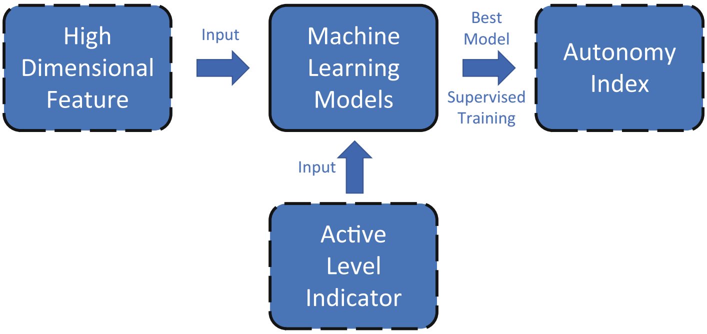

Fig. 1. Illustration of generation flow of learner autonomy index.

To represent and formalize the learner's autonomy level, we combine the multi-dimensional user behavior feature and extract an active level indicator vector from the user progress. We capture the user activity in several weeks and check whether they are actively engaging the online course and finally tag the active learner with Boolean value "True", and vice-versa.

Such active level vector and user behavior feature are input data set for multiple machine learning models. The indicator vector serves as a supervised training target and the best model after training and evaluation will be selected to further predict the user autonomy index.

Clustering-Based Behavior Identification Model. With learner autonomy feature extracted from the front-end model, we apply Gaussian Mixture Model to divide user behavior into different clusters. Gaussian mixture model is a probabilistic clustering method that assumes that all data samples are generated by a mixture of multiple mixture multivariate Gaussian distributions.

$$p(x) = \sum_{i=1}^{k} \alpha_i \cdot p\left(x \mid \mu_i, \Sigma_i\right) \tag{1}$$

$p\left(x \mid \mu_i, \Sigma_i\right)$ is the probability density function of n-dimensional random vector x that obeys Gaussian distribution.

$$p(x) = \frac{1}{(2\pi)^{\frac{n}{2}} |\Sigma|^{\frac{1}{2}}} e^{-\frac{1}{2}(x-\mu)^T \Sigma^{-1}(x-\mu)} \tag{2}$$

Gaussian mixture models are trained using maximum likelihood estimation, maximizing the following log-likelihood function:

$$L = \log \prod_{j=1}^{m} p(x) = \sum_{j=1}^{m} \log \sum_{i=1}^{k} \left(\alpha_i \cdot p\left(x \mid \mu_i, \Sigma_i\right)\right) \tag{3}$$

This log-likelihood function should be solved using Expectation-Maximization to use the existing data to determine the optimum values for these variables and then finds the model parameters, including mean vector x, covariance matrix Σ and mixing coefficients α. In order to choose the number of clusters K, a criterion for measuring the model's suitability which balances the model fit and the model complexity has to be used. One of the most used information criterion is BIC, which is a likelihood criterion penalized by the number of parameters in the model.

$$BIC(L) = -2\,L + r\log{(N')} \tag{4}$$

L is the log-likelihood function. r is the number of free parameters, and N' is the number of cluster components. With the BIC criteria curve, we can determine the cluster components with appropriate BIC loss.

4 Experiment

4.1 Data Processing Pipeline

Our data set contains MOOC data from 2015 to 2018, covering a large time domain, while the courses at the initial stage might lack detailed curriculum design. For instance, online problem function are not used by some courses in 2015, which induces many empty entries in active/reflective dimensions with zero value. We further analyze the distribution of each data dimension and filter the outliers at the beginning of data processing pipeline. After outlier filtering, we standardize features by removing the mean and scaling to unit variance. To reduce the data dimension, we apply PCA(Principle Component Analysis) to the learning behavior feature matrix by projecting each data point onto only the first few principal components to obtain lower-dimensional data while preserving as much of the data's variation as possible.

4.2 Learning Autonomy Model Training Result

Candidate Models. We select several modern machine learning models as candidates, including Logistic Regression, K Nearest Neighbour, Random Forest, Decision Tree, Support Vactor Classifier, and Xtrim Gradient Boosting Classifier. All the model parameters are default given by sklearn package. Same training set and test set are prepared to all candidate models to conduct a fair comparison.

Prediction Performance. Figure 2 demonstrates different models' prediction accuracy on learning autonomy task. The x axis represents false positive rate and y axis represents true positive rate. Lower false positive rate means better prediction performance. We plot the AUC (area under curve) score to evaluate the model performance. In our experiment, XGBClassifier shows the best accuracy and its AUC is 0.85.

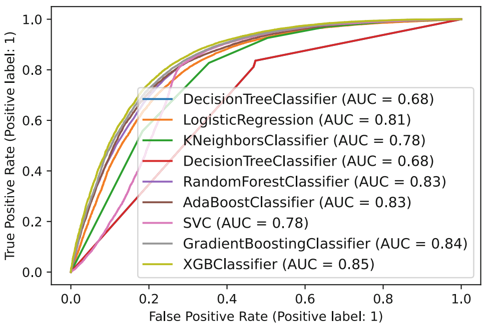

Fig. 2. Prediction accuracy of different models

4.3 Learning Behavior Clustering

Criteria of Number of Components. For Visual/Verbal dimension, the criteria of selecting cluster number is BIC and AIC score. We calculate the criteria under different number of clusters and plot the score variation with cluster number (Fig. 3).

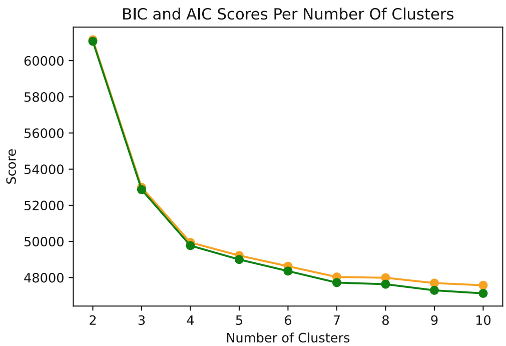

Fig. 3. BIC score variation with cluster number

From the BIC and AIC score, we set the target cluster number for Visual/Verbal and Active/Reflective dimension as 5.

Clustering Results. With the given cluster number, Gaussian Mixture Model can produce clustering results on the data set after outlier filtering and PCA transform. Every cluster's behavior variable average value is shown in the Table 3. Only several important variables among every learning behavior dimension are selected for the simplicity of illustration.

There are at most 5 clusters C1-C5 in the top row, following an ascending order, which means C5 group contains the most "Visual", "Active", or "Social" learners.

Table 3. Clustering Result of Different Learning Style Dimensions

Category	Type	C1	C2	C3	C4	C5
Visual/ Verbal	Seek	19.90	20.75	34.24	95.91	161.7
	Play	49.39	81.68	137.9	144.2	253.5
	Pause	62.68	125.1	224.2	158.7	273.6
Active/ Reflective	Progress	5.04	11.49	18.27	18.47	53.5
	Wiki	127.3	152.0	200.6	311.3	515.6
	Answer	15.26	59.95	19.71	102.1	37.45
Social/ Alone	Thread	0.01	2.01			
	Comment	0.80	4.49			
	Forum	4.61	22.8			

Following figures demonstrates Visual/Verbal and Active/Reflective dimension clusters.

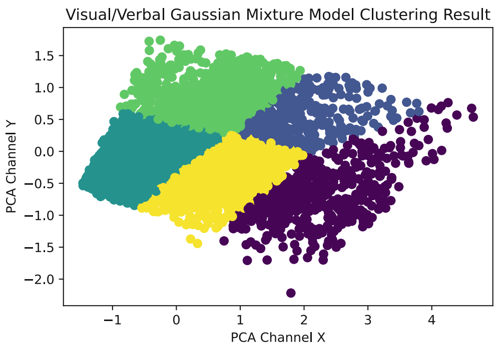

Fig. 4. Visual/Verbal dimension clustering result

From Fig. 4, the Visual/Verbal dimension are well grouped into 5 clusters. The left-most group C1 has the most learners, which is more dense than the other clusters. The right-most cluster C5 is more sparse and has some far data points, indicating the variation among C5 learners is more than the other groups. C5 group seek, play and pause video behavior average is highest among all the five clusters. It means learners from this group really rely on video information to during the online courses, and visual information is more informative for these learners.

Figure 5 demonstrates the Active/Reflective dimension clustering result on the behavior feature matrix after PCA transformation. Active learners pay more

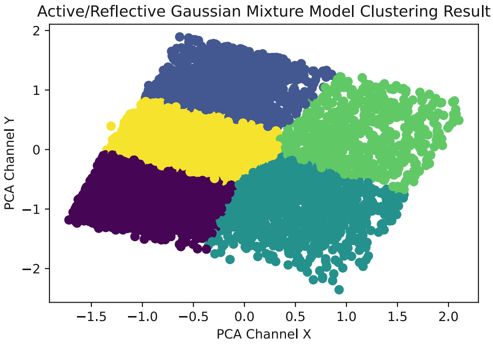

Fig. 5. Active/Reflective dimension clustering result

attention to their learning progress to keep themselves aware of their learning status. Also, they usually check the course wiki and actively answer the course problems.

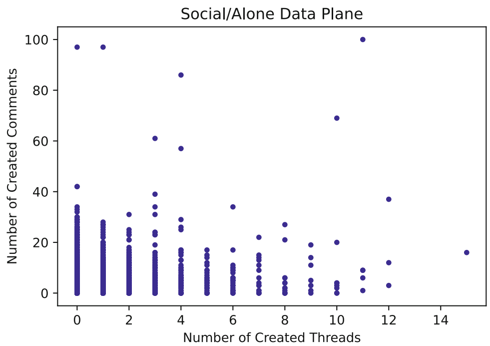

Fig. 6. Social/Alone data plane

Figure 6 is the Social/Alone dimension data plane. For the sparsity of created thread number, clustering into 2 groups is enough for the purpose of learning behavior classification. Most C1 learners are used to learn alone rather than communicating with others through the forum. Besides, few C1 learners create threads but they also click the forum to get information. Both C1 and C2 learners prefer to create comments and click forums rather than create threads by themselves.

5 Conclusion

Learning style classification can be beneficial for teachers to realize different learners' preferred learning method and design adaptive teaching strategy to enhance the course quality. In this paper, we propose a modified learning style theory model for MOOC education and apply a hierarchical learning style classification model on XuetangX MOOCCUBE data set and conduct data analysis on the learner behaviors in MOOC settings. The clustering result of our model can be used for improving online platform strategy to better motivate online learners.

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Intelligent Experimental Teaching Auxiliary Platform Based on BERT

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Abstract. Due to the problems of poor scalability, difficult experimental evaluation, and the lack of teaching data analysis and collaborative sharing in traditional experimental teaching platforms, this paper designs an interactive and scalable intelligent experimental teaching auxiliary platform BERTDS based on deep learning algorithms and computer technology. The platform provides a wide range of functions, such as the release of experimental resources, online Q&A, cloud storage sharing, automatic evaluation, similarity detection, evaluation and assignment management, etc. This paper first introduces the design idea and overall architecture of the experimental platform based on the deep learning BERT framework; then expounds the design of the organization module and automated evaluation engine that support a variety of experimental schemes and the distributed deployment scheme of the server; finally, through the actual application data analysis and user Research feedback to prove the feasibility and effectiveness of the platform.

Keywords: Intelligent teaching system · automatic evaluation · BERT · Experiment platform

1 Introduction

The experimental teaching platform based on the mobile Internet can usually effectively use computer technology and electronic resources to provide students with an open and interactive experimental environment [1]. A quality platform can assist teachers to share experimental materials, manage experimental progress and correct experimental assignments, and promote the development of online and offline mixed experimental teaching activities [2, 3]. The process of computer experiment teaching commonly involves a wealth of course practice content [1]. However, due to the limitations of traditional teaching methods, the course usually focuses on theoretical basic verification experiments in the experimental part, and rarely involves the expansion of practical application problems. The online experimental teaching platform has the advantages of functional diversity, high efficiency and safety, so it has been widely used in the teaching practice by many colleges and universities [4, 5]. However, the existing experimental teaching

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platforms still have some deficiencies in terms of flexibility, ease of use, accessibility, controllability and user-friendliness [6, 7], such as: (1) existing course-related open source software platforms do not support personalized experimental projects, complicate installation process and deployment, and poor scalability and flexibility. (2) Some fee-based experimental platforms have high procurement costs. Due to their copyright restrictions, many advanced functions need to be paid for use, which is difficult to meet the real needs of experimental teaching in this course. (3) Many existing online experiment platforms focus on the development of basic functions and lack effective teaching big data analysis, which leads to the inability to effectively mine students' course learning and experiment-related data. At the same time, the experimental question bank provided by the existing platform is mainly some simple verification experiments, which cannot support the cultivation of students' ability to solve complex problems.

Therefore, in order to meet the needs of online teaching of computer-related experimental courses, we integrated existing software and hardware resources, designed and implemented our own BERTDS, a lightweight and scalable online experimental teaching service platform to intelligently assist teachers and students in carrying out rich experimental teaching activities. Compared with the existing experimental teaching system, the BERTDS system has the following innovations:

- *Lightweight and extensible:* The BERTDS system is customized for computer experiments. It adopts modular development mode and microservice architecture for flexible software deployment. It has the characteristics of low coupling, light weight and extensibility, provides flexible and personalized experimental services for teachers and students, and supports external network and campus network access to ensure the security and stability of the system.
- *Cloud storage and community exchange and sharing mechanism.* The cloud storage module of the BERTDS system provides teachers and students with convenient multimedia resource storage and sharing functions. The community communication module adopts a rich text editor, Multi-function Text Editor (MTE), which can maximize the presentation of teachers and students' thinking, and provide convenience in conducting online experiment exchanges.
- *Automated assessment and intelligent data analysis.* Based on the BERT self-assessment framework, the BERTDS platform provides an open assessment interface to assist teachers in scoring more professional programming and subjective questions more accurately and professionally. The intelligent data analysis module can record various data in the experiment, excavate and intelligently evaluate the problems existing in experimental teaching, and provide teaching big data support for curriculum reform.

2 Requirement Analysis of BERTDS

The BERTDS aims to help teachers organize the whole process of experimental teaching and improve the communication and interaction between teachers and students. Although there are many existing online experimental platforms, in order to better meet our actual teaching needs and provide more flexible teaching auxiliary functions, we decided to integrate existing software and hardware resources to develop our own intelligent experimental teaching auxiliary system. Through preliminary research and analysis, it is found that "online teaching, online experiment, automatic evaluation, online examination, performance analysis, similarity detection, cloud storage sharing and online Q&A" are the most urgent development tasks. Therefore, the following features have been selected to be developed:

- Cloud storage and management of experimental data: Building a cloud storage module can provide teachers and students with personal network disk space for storing and managing multimedia experimental resources.
- Excellent homework sharing management: It can assist teachers in selecting excellent homework, and then provide students with services for submitting and sharing multimedia resources such as videos and PPT. The quality reports can be made publicly available as experimental reference templates for other students.
- Automated assessment and performance analysis management: The existing experimental assessment form requires teachers to spend a lot of time in organizing the test papers, collecting and correcting the experimental report submitted by each student. In addition, post-test scoring and performance analysis are difficult. Therefore, it is necessary to introduce related technologies of artificial intelligence to assist teachers in experimental evaluation and performance analysis.
- In addition, the most important requirement is the management of students and courses by teachers, because the organization of experimental teaching, the release of course resources, teaching Q&A and online experiments are the basic modules of the platform.

3 Design and Implementation of BERTDS

3.1 BERTDS Architecture

Based on the previous demand analysis, our BERTDS system adopts a modular design mode to ensure the scalability of the system. The platform is designed and implemented using the classic MVC framework. This design enables the BERTDS system to insert new data entities into the database according to new requirements, and add the codes of their respective functional modules, which is highly scalable. Figure 1 is a simple schematic diagram of the BERTDS system architecture. The platform centrally deploys the core functional modules of the system on the server, and users can access the course resources on the experimental platform only through a Web browser.

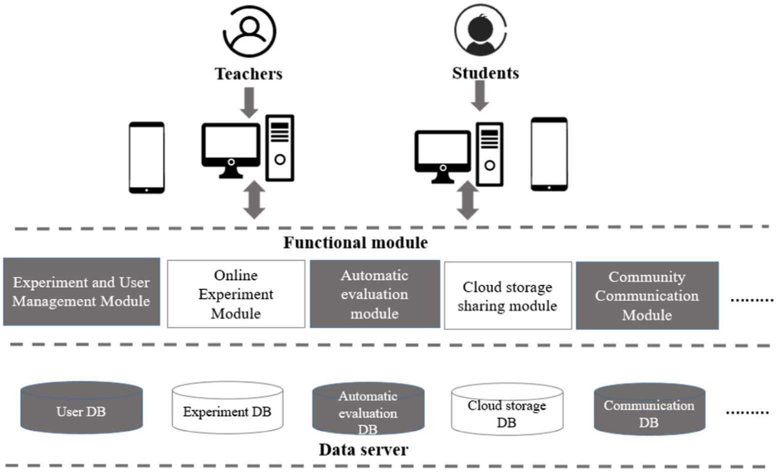

Fig. 1. The Architecture diagram of the BERTDS system

3.2 BERTDS Development Technology

The platform development and implementation technology are shown in Fig. 2, with C# as the core language and Vistual Studio Code as the development tool; the front-end implemented by HTML + Sass + Vue and the VFluentDesign component library independently developed by the team; the back-end implemented based on the Dotnet Core framework, and the database Adopt MSSQL. The Online Judge uses Node.js with Redis and MySQL as data storage, and encapsulates it into a Docker container microservice to provide an evaluation interface. The online assessment algorithm is implemented based on the self-reported assessment framework of the BERT model, and the similarity detection algorithm is implemented based on the open source JPlag framework.

3.3 Experiment Resource Management and Sharing

The BERTDS system has built a cloud storage space to allocate personal network disks for teachers and students, which is convenient for teachers and students to store and manage experimental resources, and promote cooperation and exchanges between students through the sharing of multimedia teaching resources. The community communication module deepens students' understanding of the experimental content through online discussion of experimental knowledge points, thereby improving students' enthusiasm for learning and participation. Teachers can also more clearly understand the learning progress of different students, adjust the course progress in real time, and carry out personalized experimental teaching. At the same time, the resource sharing of students across different classes, especially the excellent homework report, can provide students with richer experimental ideas and expand the depth and breadth of the experiment. As shown in Fig. 3, some learning resources shared by excellent homework are listed. The platform takes students as the main body, promotes the development of online experimental teaching through network collaboration, and effectively solves the problems of single form of traditional computer-based experimental teaching, insufficient interaction between teachers and students, and unreasonable evaluation methods. Given the advantages of laboratory open conditions and network resources, experimental teaching will not be limited by time and space [8, 9].

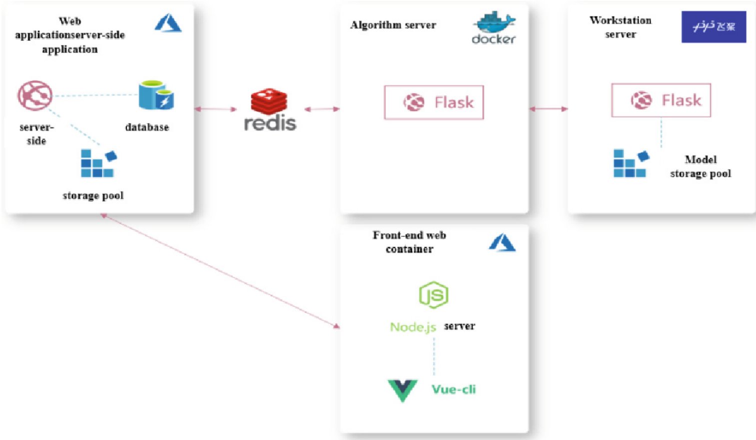

Fig. 2. BERTDS system development technology implementation

4 BERTDS Automatic Evaluation Module

The traditional computer experimental teaching assistant platform has problems such as low experimental evaluation efficiency and difficulty in collecting and analyzing experimental data. In order to solve these problems, we propose the development of an automatic evaluation module based on the BERT self-viewing roll framework.

Fig. 3. List the learning resources of some excellent assignments shared by students

4.1 Automatic Evaluation Process

In the automatic evaluation process, the submitted experiment code and written report will be stored in the system database after students complete the experiment, and each evaluation record contains an ID identifier. The system automatically transmits the code to be evaluated and other experimental reports to the evaluation engine database on a regular basis, and the evaluation engine adds the code in the database to the Redis queue. The evaluation machine will obtain experimental codes in batches from the queue and compile them. If the compilation is wrong, it will save the error message to the database and return the compilation error message. If the compilation is passed, it will automatically run the program, check the execution time and memory of the program, and judge the execution result of the program. The evaluation program of the platform supports a variety of programming languages. When compiling, different compilers will be selected according to different programming languages, such as Python, Java, etc., which can be compiled into binary files and then interpreted and executed. After the automatic evaluation, if the answer is wrong or there are some errors, students can improve the experimental ideas and optimize the experimental code according to the error message returned by the system.

For the experimental report of subjective questions, the automatic evaluation module can perform automatic evaluation based on the weakly supervised learning strategy. As shown in Fig. 4, it uses text summarization technology and grammatical analysis to extract abstracts and evaluate the grammatical quality of subjective questions to assist teachers in scoring.

Fig. 4. Automatic evaluation of subjective questions based on weakly supervised learning strategy

4.2 BERT Evaluation Framework

The BERT evaluation framework is based on the sentence vector text similarity calculation model proposed by BERT and adopts a data enhancement algorithm based on a weakly supervised learning strategy. BERT is a language understanding model proposed by Google in 2018. It is a substitute for Word2Vec, which greatly improves the accuracy of experiments in the field of NLP [10]. The BERT model uses Transformer as the main framework of the algorithm [11], which can more thoroughly capture the bidirectional relationship in sentences. The algorithm uses the multi-task training objective of Mask Language Model (MLM) [6, 8] and Next Sentence Prediction (NSP) [8]. It essentially learns a good feature representation for words by running a self-supervised learning method on a massive corpus. Its network architecture uses a multi-layer transformer structure, which is formed by stacking several encoders and decoders, and converts the distance between two words at any position through the attention mechanism [12, 13].

In the realization of the subjective question scoring task, the model structure is shown in Fig. 5. The evaluation framework enables the model to have a strong scoring ability when facing new short-answer questions without relying on the data of student responses and teacher ratings.

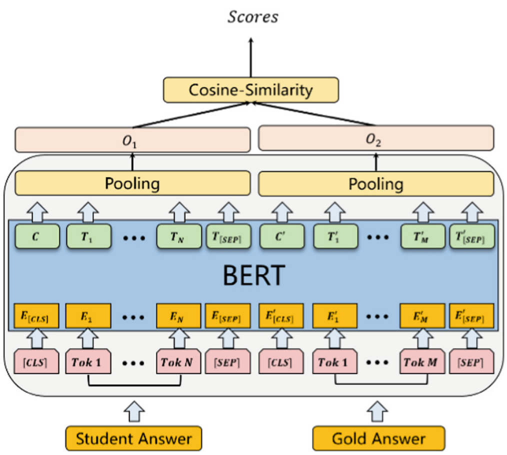

Fig. 5. Structure of BERT-based automatic evaluation model

The scoring of subjective questions is based on the calculation of text similarity. By calculating the text similarity between the student's answer and the reference answer, the scoring is carried out. The input of the model is the splicing of the student's answer and the reference answer. For better parallel computing, the lengths of student answers and reference answers will be padded to a fixed length L. Among them, the [CLS] mark is added to the head of the student's answer and the reference answer, and the [SEP] mark is added to the tail. [CLS] indicates that the feature is used for classification models, and for non-classification models, [CLS] conformance can be omitted. [SEP] represents a clause, which is used to disconnect two sentences in the input corpus. In the output layer of the model, the output features are divided again according to the length L, so as to obtain the features of the student's answer and the feature of the reference answer respectively. O_1 and O_2 are obtained by performing an average pooling operation on the two features, and then the cosine similarity is used to calculate the similarity of O_1 and O_2, resulting in a score ranging from 0 to 1. Finally, the score is scaled according to the total score corresponding to the original question to get the final score.

The framework has been integrated into the evaluation kernel for algorithm design problems. In this module, text summarization technology and grammatical analysis are used to extract abstracts and grammatical quality of subjective questions, and assist teachers in scoring subjective questions. Provide an open evaluation interface to meet the needs of more accurate and professional scoring of highly professional topics. The automatic evaluation module can also save experimental evaluation results, and use these evaluation data to provide effective big data support for curriculum teaching reform.

4.3 Evaluation Server Deployment

In order to solve the problems of system crash and service suspension caused by instantaneous high concurrent access, a distributed cluster environment is used for deployment in the design process of the evaluation module to meet the stability and efficiency of the automatic evaluation module [14–17]. As shown in Fig. 6, DB-server is deployed for database interaction, which is responsible for obtaining evaluation tasks from the database and writing the results back to the database at the end of the evaluation. Next, NOJ-server evaluation servers are deployed. The evaluation machine only communicates with the DB-server. After the evaluation is completed, the results are returned to the DB-server, and then the DB-server writes the results to the database. The DB-server server is used to coordinate each evaluation machine OJ-server, thereby reducing the operation of the database, thereby effectively improving the speed and security of the system evaluation.

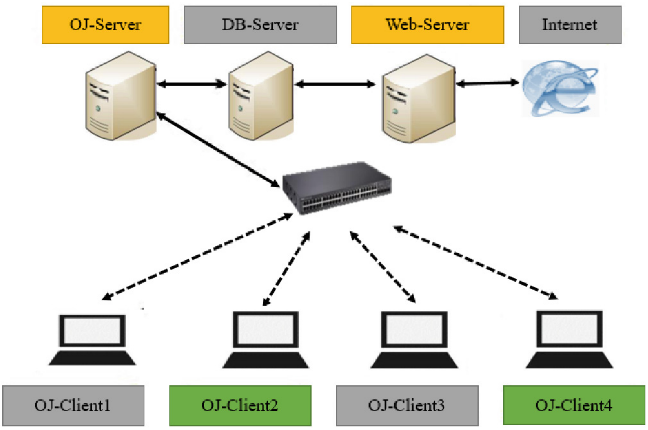

Fig. 6. Distributed evaluation server cluster

5 Evaluation

The BERTDS system has been applied in several courses, and the results have proved its effectiveness and practicality. The use of the platform can also help the research group to collect relevant data of the experimental process, and analyze and feedback to evaluate its advantages. Here we show the application of the BERTDS system in the "Algorithm and Data Structure Practice" course.

The "Algorithm and Data Structure Practice" course is a basic course for computer students. Through the study of this course, students can improve their algorithm design and analysis ability, hands-on practice ability and ability to solve complex engineering problems. The platform supports cross-platform services, and users can conduct experiments by accessing: http://ds.fzu.edu.cn/ through the Web.

Case 1: Application of cloud storage sharing and community communication module
The BERTDS system supports both the multimedia experiment resources uploaded by teachers and the sharing of other course resources provided by students, as shown in Fig. 7. In the "Algorithm and Data Structure Practice" course, teachers can present various experiments-related videos and lesson plans to students through the cloud storage sharing module, helping students master some difficult knowledge points. The multimedia resources uploaded by teachers include micro-classroom videos or other reference materials for students to preview and review after class, which expands the depth and breadth of the experimental content. After teach evaluate and select excellent homeworks, the selected students can upload their own multimedia presentation materials on the personal network disk to show their experimental ideas. Other students can learn and like them, which can help students share and exchange novel experimental solutions.

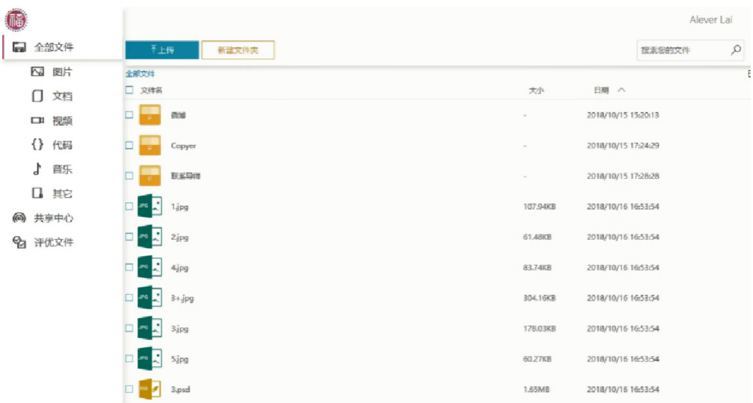

Fig. 7. Cloud storage sharing module of BERTDS system

At the same time, as shown in Fig. 8, teachers and students can interact online through the community communication module. Students can also initiate some experiment-related topics on the platform, and teachers and students can reply to these questions. Students can even solve problems they encounter with other students through this module. It is beneficial for students who are interested in experiments to expand their practice and stimulate their enthusiasm for learning and subjective initiative.

Case 2: Application of automatic evaluation and data analysis module
The automatic evaluation module of the BERTDS system provides a systematic solution for experimental exams, which has been fully integrated into the entire teaching process

of the "Algorithms and Data Structures Practice" course, and is used in several of our courses to organize all exams, including course quizzes, mid-term exams and final exams. With the automatic evaluation module, teachers can flexibly organize exams, design exam questions, and evaluate them. Teachers can put the designed questions into the question bank at any time, and then select the required questions to form the test. The list of students taking the test and the test time can be set in advance. As shown in Fig. 9, after the test being completed, the automatic evaluation module of the BERTDS system can automatically transmit the code to be evaluated to the evaluation engine database on a regular basis, and the evaluation machine will obtain the experimental results in batches from the queue, conduct evaluation, and return the score.

Fig. 8. BERTDS Community Communication Module

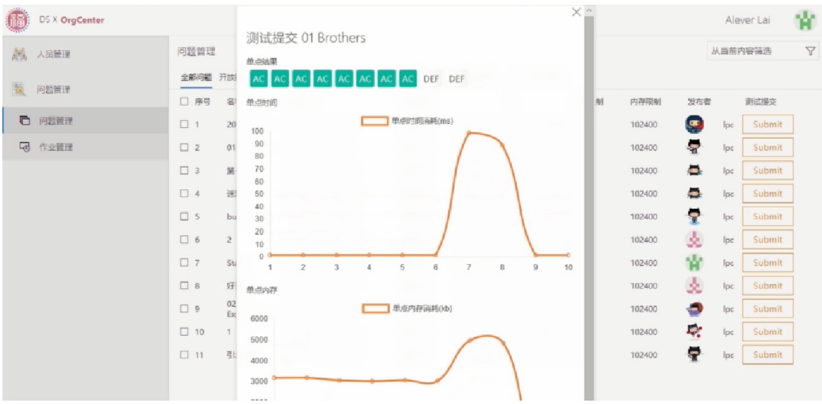

Fig. 9. The automatic evaluation module of the BERTDS system

Since the BERTDS system does not rely on Internet connection to operate, it can be deployed in a dedicated local area network. Students can conduct experiments on the campus network or computer room local area network during the test, which can reduce the interference of external networks and ensure the security of the system and test data. Figure 10 shows the real scene of students conducting final experimental evaluation through the BERTDS system. This test is arranged in the laboratory computer room, and candidates only need to log in to the platform through the computer room computer to take the test.

Fig. 10. Students conducting final experimental evaluation through the BERTDS system

In addition, teachers can also conduct statistical analysis of teaching situations through the data analysis module, and the BERTDS system will automatically record and count the students' online experiments, such as study time, number of experiments, number of evaluations, and experimental results. By choosing the data analysis plan, teachers can grasp the students' learning dynamics in time, adjust the progress of the experiment, and provide data support for the reform of the curriculum.

The auxiliary effect of BERTDS experimental teaching

The BERTDS system not only can help teachers can better organize all experimental resources and the entire teaching process, but also can improve students' practice experience. Figure 11 is an analysis of the experimental results of some students taking this course. Since the platform was developed and launched in 2005 and upgraded in 2018, it has served nearly 10,000 teachers and students in the school (including nearly 2,600 service users during the epidemic since 2020), meeting the actual needs of experimental course teaching. The platform is used by undergraduates and postgraduates, involving students majoring in computer, software engineering, big data and artificial intelligence. The accumulated page views were 30,462 times, and 348 experimental tasks were released.

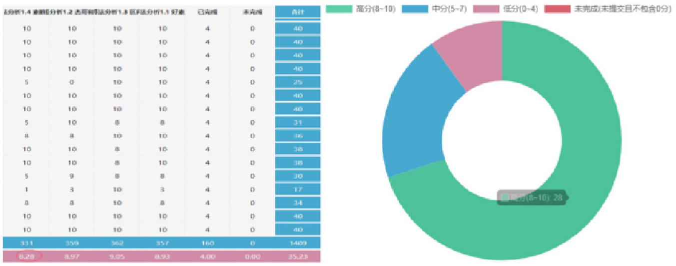

Fig. 11. Analysis of the experimental scores of some students in this course

On average, each person downloaded course resources 6.65 times a week, and the assignment submission rate reached 96.9%. The online experiment duration survey of more than 300 students who have used the platform is shown in Table 1. The average online experiment time per person is 3.86 h per week. It can be seen from the above data that students are highly motivated and motivated to learn independently through the BERTDS system.

Table 1. Questionnaire results of 300 students using the BERTDS system

Time Spent	Percent
At least 2 times a week, more than 30 min each time	18.7%
At least 2 times a week, more than 1 h each time	12.7%
At least 2 times a week, more than 2 h each time	21.0%
At least 4 times a week, more than 30 min each time	22.0%
At least 4 times a week, more than 1 h each time	10.7%
At least 4 times a week, more than 2 min each time	15.0%

We also collect feedback from students who have used the BERTDS system. Most of the students expressed their approval of the module design and functional application of our platform, and considered the platform to be very helpful to their course practice. Table 2 shows the result of a satisfaction survey of 300 students who have used the platform. Among them, 66% of the students expressed "very satisfied", 25.3% of the students expressed "satisfied", and 6.7% of the students expressed "somewhat satisfied".

From 2005 to 2022, the platform was gradually refined and adopted in several of our lab courses. We have enhanced existing modules such as resource sharing, online experiments and teaching activity management, and introduced new functional components (such as automatic assessment and similarity detection modules) to meet the needs of teachers. These improvements are not only beneficial to teachers' interactive teaching process, but also to students' autonomous learning, and significantly improve students' practical ability. According to the survey, the three most popular functions of the BERTDS system are: cloud storage module, community exchange center and automatic assessment module. In terms of functional design, experimental project planning

Table 2. Survey on Experimental Teaching Satisfaction of BERTDS System

Evaluate	Number of Students	Percent
Very Satisfied	198	66.0%
Satisfy	76	25.3%
Quite Satisfied	20	6.7%
Generally	6	2.0%
Dissatisfied	0	0%

and teaching management, the platform focuses on improving students' practical ability and ability to solve complex engineering problems. The big data analysis module of the platform can also provide strong data feedback support for the comprehensive process evaluation of the course and course teaching reform, which can promote the improvement of teaching methods and help to realize the personalized teaching of "teaching according to aptitude".

6 Conclusion

The BERTDS practical teaching assistant platform proposed in this paper can well meet the needs of practical teaching of computer-related courses. The platform takes the characteristics of computer-related majors into consideration, and focuses on the needs of talent training, and develops a system of "supporting extracurricular exploration with rich expansion materials, strengthening practical training with automated homework evaluation, and ensuring fairness and justice with comprehensive anti-plagiarism checks". It provides practical teaching network support. Due to the modular design and microservice architecture, the platform can adapt to different needs through different functional configurations, and be deployed in different hardware or network environments at the same time. The platform can effectively solve the problems of poor scalability of traditional experimental platforms, difficult experimental code evaluation and lack of intelligent experimental data analysis. In terms of technical implementation, the automatic evaluation of subjective questions is realized based on the sentence vector text similarity calculation model proposed by BERT; at the same time, a data enhancement algorithm based on a weakly supervised learning strategy is adopted to achieve strong scoring ability and support cross-platform, and language diversity. The platform is rich in functions and novel in design, which can effectively solve the problems of "difficult teaching, difficult interaction and difficult evaluation" in computer experiment courses. The practical application proves that the platform can effectively assist teachers to carry out intelligent experimental teaching and help students carry out personalized online experiments.

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AI Interaction Design Driven Software Engineering: An Exploratory Experimental Teaching Method

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Abstract. The Human-centered Artificial Intelligence (HAI) report shows that it is crucial to overcome the challenge of using AI technology effectively and responsibly for constructing intelligent systems. To address these challenges, an exploratory experimental teaching method driven by an AI interaction architecture designer is proposed. This teaching method involves two phases. In the first phase, interaction designers analyze user interaction scenarios and design the user experience, including interaction modeling and user interface prototyping. In the second phase, software engineers use AI methods to develop the intelligent system based on the user interface prototype. The AI interaction architecture designer plays a critical role in deciding the appropriate AI methods to meet user needs. The success of this teaching method is demonstrated by the successful delivery of intelligent systems. This method can enable effective and responsible use of AI technology in building or refactoring intelligent systems. Therefore, this teaching method has been validated.

Keywords: Artificial Intelligence · Interaction Design · Software Engineering

1 Introduction

Human-Computer Interaction (HCI) is a discipline that studies the design, evaluation, realization, and relevant observation of interactive computer systems [1]. Its theories are derived from computer science, industrial design, visual communication design, and other disciplines.

Currently, the new wave of artificial intelligence (AI) technologies, including computer vision and natural language processing, have made breakthroughs in recent years [2]. In the past few years, new human-computer interaction scenarios such as autonomous driving and smart speakers have emerged. Natural and efficient intelligent interaction paradigms are widely used in these scenarios, resulting in a new human-centric user experience. Previous algorithm research shows that model innovation has developed to pay more attention to the application of specific scenarios. To effectively put artificial intelligence technology into specific application fields, we need the discipline of AI interaction. This discipline should be a combination of human-computer interaction and artificial intelligence.

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It is worth mentioning that Alibaba founded the Academy for Discovery, Adventure, Momentum, and Outlook (Alibaba DAMO Academy) [3], which covers the research field of "Human-Computer Natural Interaction". It is the combination of artificial intelligence technology and HCI. Stanford University also officially announced the establishment of the "Human-Centered AI Project" intending to create the "Stanford Human-Centered AI Institute (HAI)" [4].

Therefore, we propose a project-based teaching method to provide the industry with talents who can solve the problem of turning artificial intelligence technology into products. This teaching method will combine AI software engineers and human-computer interaction designers to complete projects, to cultivate their communication and collaboration skills and inter-professional knowledge. Ultimately cultivating students will understand both interaction design and software development, becoming bilingual in technology and human-computer interaction. We name this kind of talent "AI interaction architecture designer".

2 Innovation in Content

In the early days, the main disciplines involved in human-computer interaction were computer science, sociology, anthropology, and so on. The application of schema theory in human-computer interaction is called the HCI schema. The classic human-computer interaction schemas can be divided into social psychology schemas and cognitive psychology schemas. The former includes the activity theory model, and the latter includes the information processing theory, the Keystroke-Level Model (KLM) cognitive model, and the "goal, operations, method, selections (GOMS) cognitive model". In previous human-computer interaction theories, we often focus on the basic methods and principles of user interface (UI) design, interaction design process, interaction implementation, and interaction evaluation. The focus of our teaching is the UI design process, such as the user-centered UI design process.

With the rapid development of AI, AI can be applied to more and more systems to upgrade and refactor the previous systems. In this case, software development needs to find scenarios, develop programs that can be rewarded and run for a long time, and generate commercial value and social benefits. Achieving this goal requires the participation of a human-computer interaction designer.

HAI points out that artificial intelligence itself is a general-purpose technology. This means that artificial intelligence itself has nothing to do with good or evil. Therefore, in the field of artificial intelligence and human-computer interaction, three issues should be considered. There are Human Impact, Augment Human Capabilities, and Intelligence [5].

2.1 Human Impact

Human impact means that it is necessary to study how artificial intelligence affects human society, and how human society should affect the development of artificial intelligence. Artificial intelligence may have an impact on a large number of areas such as social structure, justice, government, labor market, economy, and so on. The purpose of these studies is to guide the development of artificial intelligence.

2.2 Augment Human Capabilities

Augment Human Capabilities means that we hope to study and use some human-centered design methodologies and tools to make artificial intelligence communicate with people more effectively.

2.3 Intelligence

The Intelligence issue means that current artificial intelligence cannot provide human beings with a sufficient explanation. Current AI can do well in well-defined tasks, but each task requires large amounts of data for laborious training. It means that the next generation of artificial intelligence technology needs to be developed.

Perceptual intelligence refers to the mapping of signals from the physical world to the digital world through hardware devices by using cutting-edge technologies such as speech recognition and image recognition. There are three layers of Perceptual intelligence (see Fig. 1).

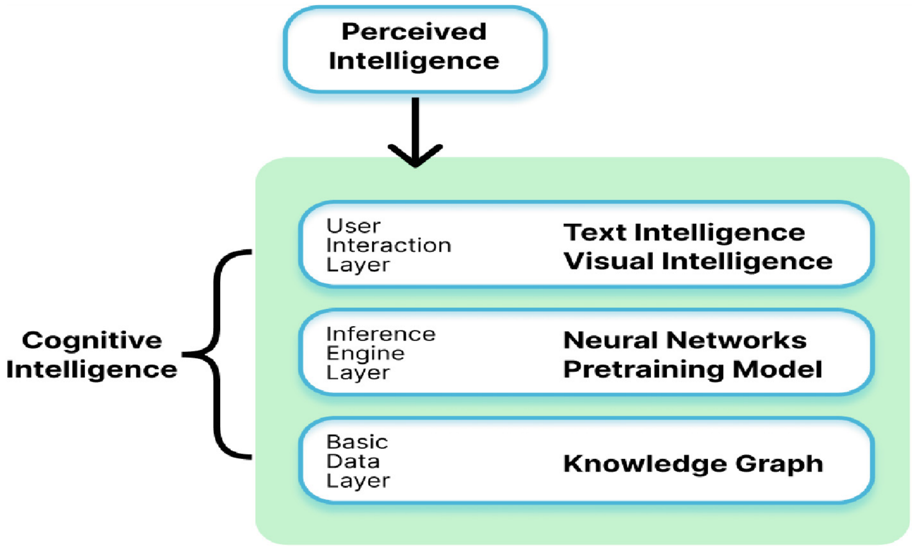

Fig. 1. Cognitive intelligence hierarchy

The User Interaction Layer. This layer emphasizes how the AI interacts with the user and how the user interacts with the AI. In real projects, this interaction takes two forms, one is text intelligence and the other is visual intelligence. There is a typical text intelligence will be introduced in the following part.

The Reasoning Engine Layer. This layer emphasizes the mode and performance of AI, which is the key to the AI system. The neural network model can be trained to achieve excellent regression and classification. The pre-training model can be used to reduce training pressure and quickly build an effective inference engine. Practical projects often take the form of a combination of the two.

The Basic Data Layer. This layer is the foundation of AI. The knowledge graph can reveal semantic networks of relationships between entities. The construction of Knowledge Graph can enhance the explainability of AI and also assist the inference engine layer to complete multi-hop reasoning.

3 Cultivation of Talents

3.1 Previous Requirements

The traditional jobs related to human-computer interaction include interaction designers, user experience designers, visual designers, information architects, user researchers, and usability analysts. Generally speaking, there is more demand for designers in the market (See Table 1).

Table 1. Breakdown of UX Job Titles [6]

UX Jobs	The rate of a team included the job
Interaction design	64%
Visual design	54%
User research	52%
Functional department design	34%
Product Manager	33%
Brand design	29%
Data analysis and big data apply	24%
Game design	21%
Creative design/plan	21%
Project manager	15%
Tech dev	14%
Industrial design	8%
others	3%

Once they are involved in work, traditional UX practitioners are most likely to learn data analysis tools, dynamic visual effect tools, and data visualization tools [6] to benefit their work career and help. Besides, correct UX students are likely to learn design collaboration tools, interactive prototyping tools, and 3d modeling or AR/VR design tools (See Fig. 2).

Besides, the investment in artificial intelligence includes data management, medical and healthcare, and so on (See Fig. 3) [7]. Except for education technology, investments

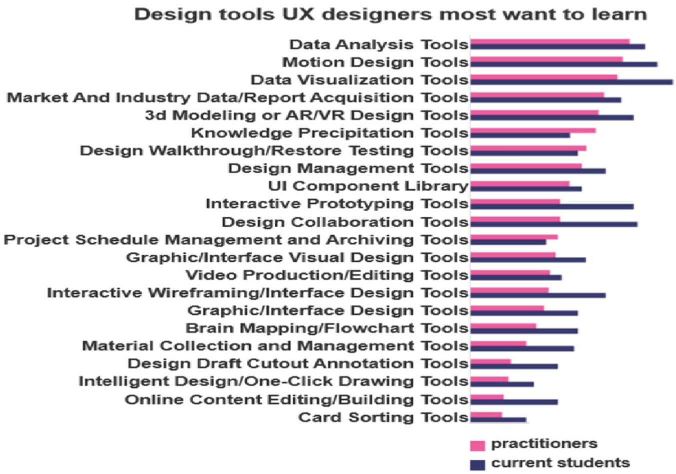

Fig. 2. Design tool UX designers most want to learn

have increased rapidly in almost all sectors. Among them, the areas with the largest investment growth are fintech, and data management, processing, cloud.

Aggregated data in Fig. 4 [7] showed in 2017–2021 the medical and healthcare category received the largest private investment globally. Following followed by data

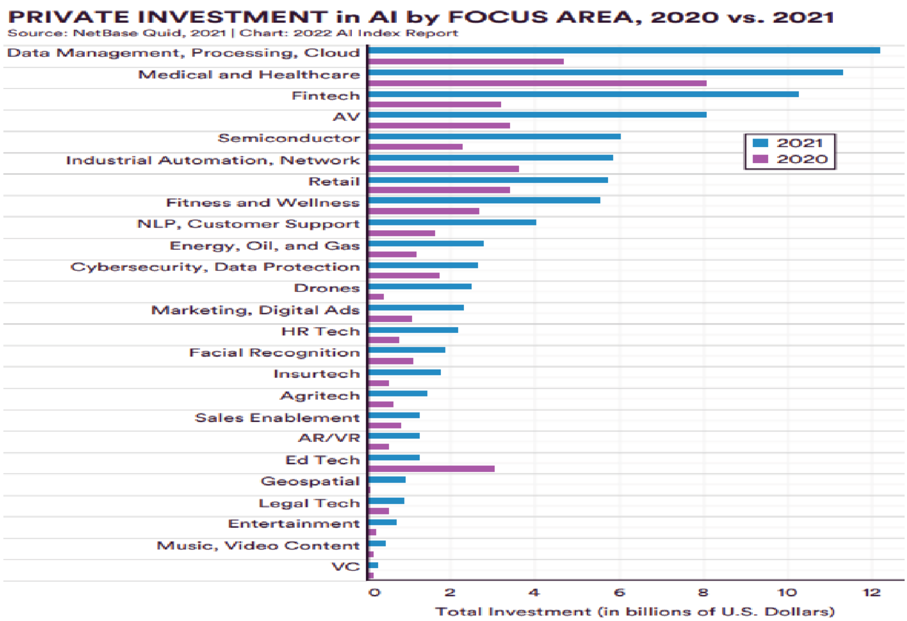

Fig. 3. Private investment in AI by FOCUS AREA, 2020 vs. 2021

management, processing, and cloud; fintech; and retail. Figures showed all of these takes more than 30% percent of investment in AI.

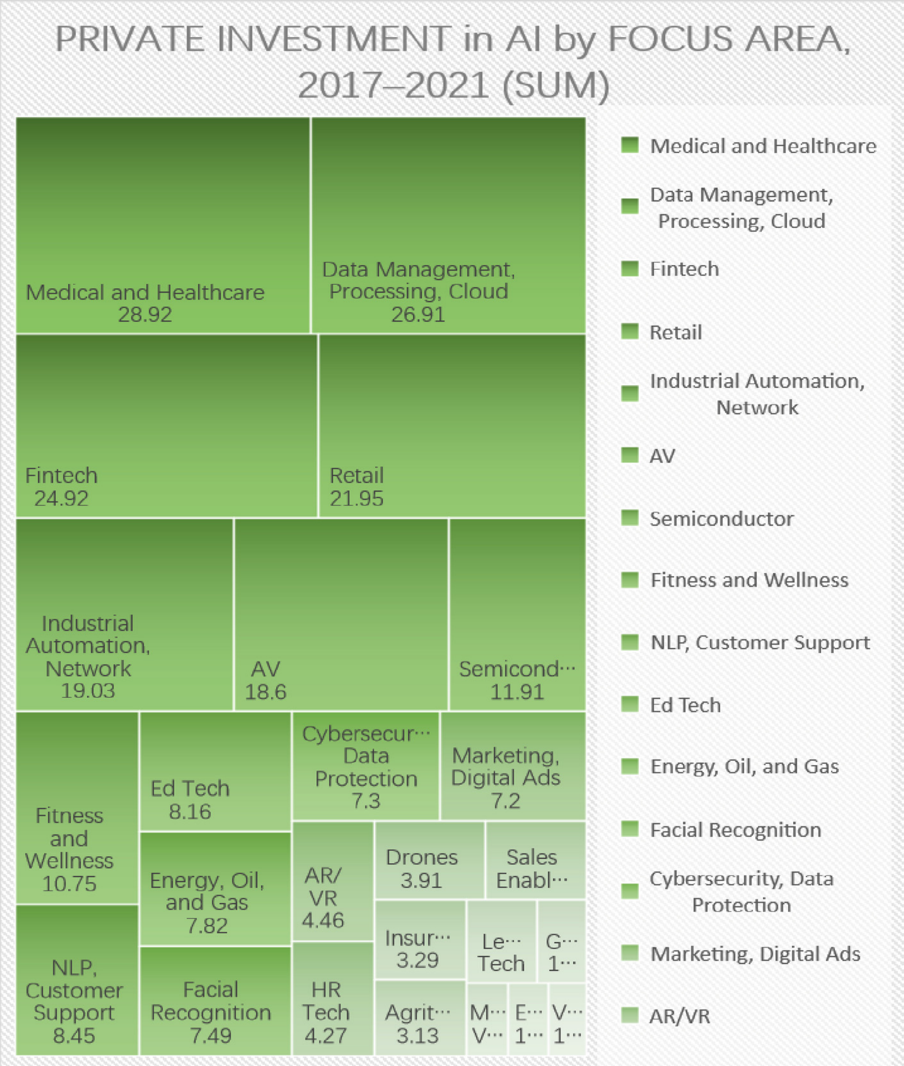

Fig. 4. Private investment in AI by FOCUS AREA, 2017 – 2021 (SUM) [7]

From this chart (See Fig. 5), it can be observed that the number of Ph.D. graduates in artificial intelligence and human-computer interaction has increased significantly in the past two years, while the number of Ph.D. graduates in software engineering has decreased significantly. Comparing these two data can significantly reflect the changing trend of the student employment market.

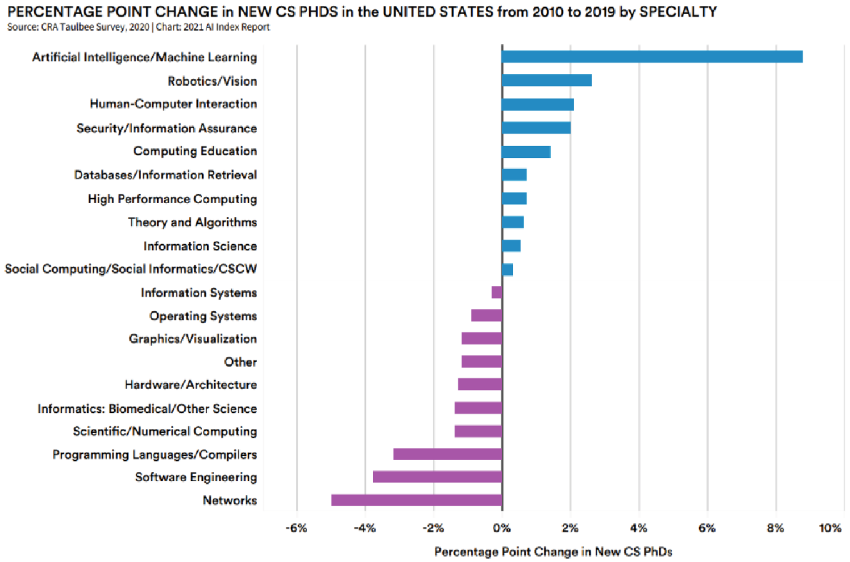

Fig. 5. Percentage point change in NEW CS PhDs in the United States from 2010 to 2019

3.2 Augment New Requirement

For current interaction design students, their attention should not be limited to the traditional industrial design industry but should focus on emerging industries.

Interaction design students should seize this opportunity. They have systematically mastered design thinking, methodology, and tools. They have also gained design and development experience in these cutting-edge areas by actively working on projects with software engineering or computer science students to participate in the development of intelligent systems.

Software engineering students should master the ability to work collaboratively with interaction designers. This ability often needs to be acquired from the process of implementing intelligent systems together with interaction designers. This capability focuses on how to obtain the support of interaction designers to improve the efficiency and effectiveness of intelligent system implementation. On the one hand, it helps improve the development efficiency of intelligent systems and reduces rework caused by insufficient research on users or unclear user needs. On the other hand, it can ensure that intelligent systems can truly satisfy the human aspect, enabling the intelligent system to generate effective value.

In the process of practice, they will have a communication gap due to their respective positions, knowledge backgrounds, and ways of thinking in the design and implementation of intelligent systems. They should use engineering languages or tools such as the double diamond design process model, agile development process model, UML language, UML formal modeling tool, or UI prototyping tool to make up for the ambiguity in natural language communication and the conflict in concepts so that intelligent System design and implementation problems can be solved more efficiently.

Judging from the effect of our exploratory experiment, in terms of talent training in colleges and universities, software engineering students and interaction design students can cooperate in exploratory experimental projects to generate obvious competitiveness in the competition for future jobs. For example, in the exploratory experimental project of the smart desk lamp project, the team created a smart desk lamp product, applied for a patent for a gesture recognition desk lamp based on deep learning, and participated in the "Skyworth Cup" innovation competition to win a gold medal. The capabilities of AI technology, software engineering, and interaction design have been comprehensively improved. At present, the demand for positions related to the design of intelligent interactive systems continues to grow [8]. These students can meet higher-level positions in the current job market.

4 Innovation in Practice

The project of an intelligent posture correction desk lamp system [8] and an intelligent consultation platform for government service are both typical examples of exploratory experiments. Table 2 shows the basics of these two projects. The following pages will describe intelligent consultation platforms in more detail.

Table 2. The basics of two intelligent systems

	intelligent posture correction desk lamp system	Intelligent consultation system
User Interaction Layer	Visual Intelligence	Text Intelligence
Interface Engine Layer	Posture Recognition Algorithm	Knowledge Graph Inference Algorithm; Inference Machine Algorithm
Basic Data Layer	MNIST CIFAR COCO	affair navigation rule; the details of affair guides
Perceptual intelligence/interactive media	look/camera; communication module	Word/Web UI input box; Browser
AI Framework	PyTorch / Tensorflow	Tensorflow / Bert / hanlp
Scenario	Posture Correction Scenario	Affair Consultation Scenario
Humanistic Factors	reassure parents; Privacy issues for teenagers and children	Citizens' higher demand for government services; Superior organization intellectualization requirements

(*continued*)

Table 2. (*continued*)

	intelligent posture correction desk lamp system	Intelligent consultation system
Interactive Design	Smartphone App interaction design	Web UI Interaction design

4.1 The Initiation Stage of the Exploratory

The students on our team have good programming abilities in C++ and python and understood the principle of machine learning. These programming foundations are mainly derived from theoretical practice and the practical development of projects.

There is an interaction designer within the team that defines the transaction consulting scenario. The consultation platform needs to enable citizens to obtain the affair guide with their conditions efficiently.

In addition, intelligent consultation platforms need to meet the human factor. Firstly, it is necessary to satisfy citizens' higher demands for government services. Secondly, system should reduce the workload of clerks instead of letting clerks provide large-scale annotated data. Thirdly, to meet the vision of government agencies, it should improve the government service capability and intelligent application level. Finally, an intelligent consultation platform needs to meet the requirements of interaction design. The system should design flexible interactive modes, such as intelligent navigation, intelligent Q&A, and intelligent affair guide retrieval.

Combining innovation and practicality, the general direction of the project is to use the knowledge graph to optimize the retrieval system. Our team start to read patents, papers, and projects related to the knowledge graph and retrieval system. After nearly a month of reading, the logical view of the architecture was preliminarily determined.

4.2 Architectural Technology Implementation View of the Project

A series of experiments are carried out to explore the implementation methods of each module logic module of the architecture (See Fig. 6). This includes five modules and one knowledge graph.

At the inference engine Layer, according to the characteristics of the project and the technical background of the team members, TensorFlow deep learning framework, Bert model, and the toolkit hanlp are selected to process the dataset.

At the basic data layer, we use the datasets obtained from the government. The datasets are about the affair navigation rule and the details of affair guides. We need to extract information from them and store them in the knowledge graph.

At last, the toolkit hanlp was used in the word segmentation and to do entity extraction and relation extraction to build the knowledge graph. Bert model tried to transform the words inputted by users into the word vector to search for similar words in the database. Through experiments, the effectiveness of the technical model is gradually confirmed and the logical module of the architecture is realized. The final system is shown in Fig. 7.

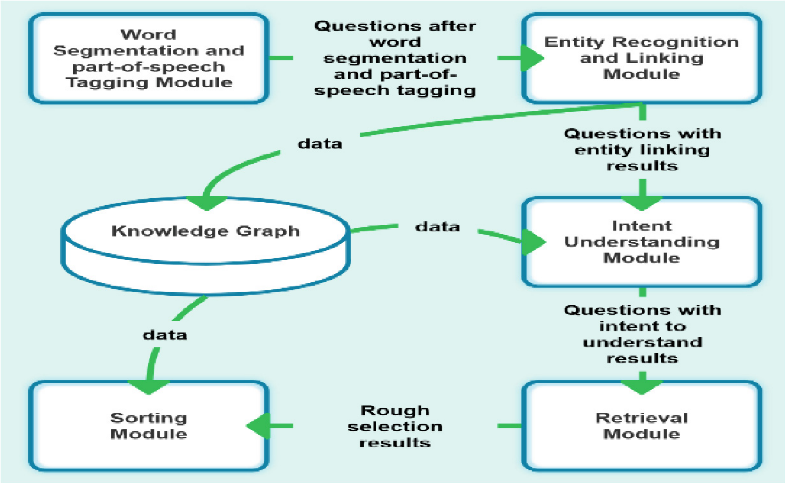

Fig. 6. Retrieval system of intelligent consulting platform

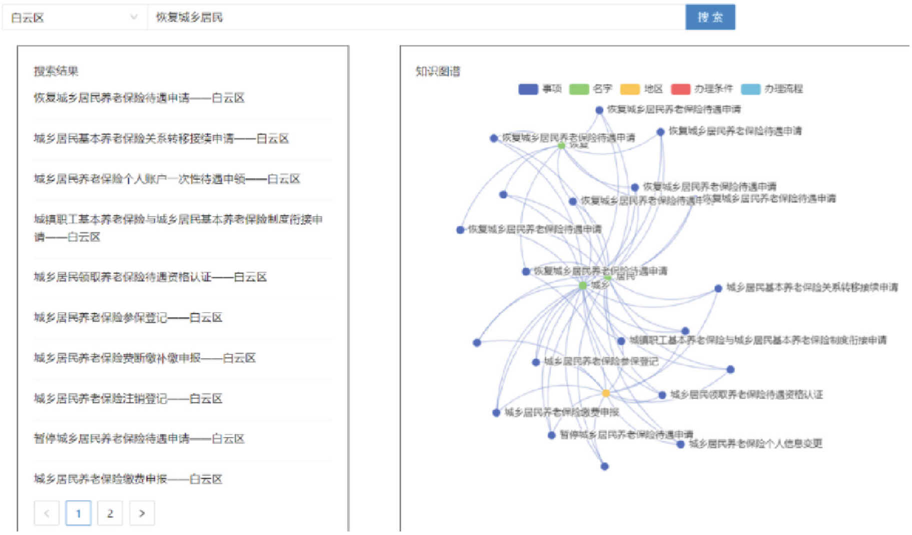

Fig. 7. This is the interface of the system. The left side of the interface displays the search results in the form of a list, while the right side displays the search results in the form of a graph.

Figure 8 provides a sample of the search word "work injury", the system returned a graph about related nodes, including the Change of personal information of industrial and commercial medical insurance and other similar affairs.

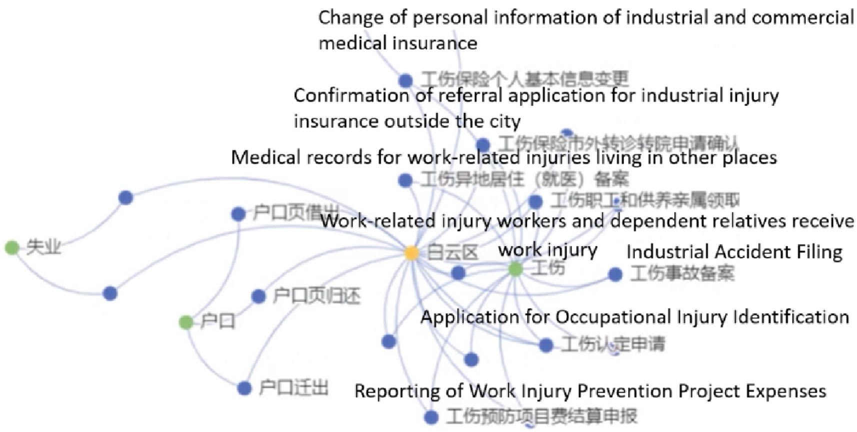

Fig. 8. Items relate to injury in the system.

5 Conclusion

In the past 3 years, we have organized software engineering students and interaction design students from South China University of Technology to implement the exploratory experimental teaching method. These practices have achieved great results [8]. Our work experience in computer vision for smart desk lamps, text intelligence for the knowledge graph, and the employment of project members support the changing trends reflected in the HAI report. Through professional training, our team members applied for invention patents. Some of them joined Tencent AI Lab, Huawei AI Intern, and ByteDance's video recommendation positions.

We are convinced that this is an efficient and reproducible process. To implement this process successfully, the instructor should organize students to learn theory related to the intelligent system design project in an orderly manner through various methods. Besides, to encourage students to collaborate on projects across majors, colleges should provide project support and innovation credits.

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International Chinese Language Education Online Teacher Training Program and Practice

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Abstract. Current teacher training at the graduate level in international Chinese language education focuses on traditional face-to-face classroom teaching methods and therefore does not well meet the needs of the international Chinese language education industry. This study is based on the SCOLT (Synchronous Chinese Online Language Teaching) distance learning program between Beijing Language and Culture University (BLCU) and Massey University in New Zealand, which assigns Chinese language learners at Massey University to a BLCU graduate student as a tutor to teach Chinese language in a one-to-one online format. Facing the problem of international Chinese online teachers' training, this paper adopts a qualitative research approach to address the issue of training international online Chinese language teaching teachers by using 450 post-class reflections from 93 student teachers. The analysis of teachers' post-class reflections revealed teachers' thinking, growth and progress. Combined with social learning theory, this study explores teacher preparation programs for international Chinese online teachers and provides ideas for international Chinese teacher development.

Keywords: International Chinese · Online Teaching · Teacher Training

1 Introduction

Online teaching has been evolving in recent years, both before and after the pandemic. International Chinese language education is in urgent need of application-oriented teachers who can adapt to new teaching forms. It is necessary to carry out practical teaching to enhance the role of practical teaching in the training of application-oriented teachers. At present, there are some problems in the practical teaching of international Chinese majors, mainly in the following aspects: (1) the practical teaching system is not comprehensive enough and lacks systematization and practicality. (2) Limited conditions for practical training and internship, and loose organization of off-campus internship. (3) The evaluation system of practical teaching is not perfect, and the assessment system is disconnected from practical teaching. At the undergraduate and postgraduate levels

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of international Chinese language education teacher training, there is a certain lag in teaching contents, emphasis on traditional face-to-face classroom teaching methods, and failure to focus on training student teachers' online teaching skills.

In order to develop Chinese language teaching and train international Chinese teachers online, Beijing Language and Culture University in China and Massey University in New Zealand established the Joint Research Center for Linguistics and Applied Linguistics in 2016, aiming to provide New Zealand and other Oceania island countries with better Chinese Teaching references and demonstrations. The purpose of this study is to report on this China-New Zealand joint research and development practice program, which assigns each Massey Chinese language learner to a Beijing Language and Culture University tutor who are already Postgraduate students who have taken courses in teaching Chinese as a second language. Each pair of teachers and students completed 5 online video sessions within the specified time, each 15 to 20 min, and the whole process was videotaped. After each video session, the trainee teacher fills in the post-class reflection form. The content of after-class reflection is in the form of text narration. The program aims to supplement the oral language ability of Chinese language learners in New Zealand, and at the same time focuses on the training of international Chinese online teachers. The two parties have successfully carried out five cycles of SCOLT (Synchronous Chinese Online Language Teaching) cooperation (Zheng 2021). This study mainly discusses the achievements in teacher training.

By examining the post-class reflections of teachers in the SCOLT program, this study analyzes the problems that often occur in teachers' online Chinese tutoring, takes appropriate actions in reflective adjustment, improves the effectiveness of online teaching, and analyzes the reasons for taking corresponding measures, summarizes the paths of intern teachers' growth from reflection, and realizes the exploration of the teacher training model for international online Chinese teaching.

2 Literature Review

2.1 Research Methodology

Canadian scholars Clandinin and Connelly made a series of educational narrative research results in the 1990s. Then educational narrative research became a qualitative research method and was widely accepted and applied (Qian and Chen 2014). Educational narrative research belongs to the research paradigm of discovery rather than proof. Educational narrative research follows a bottom-up inductive logic, usually looking for the inner structure from the narrative itself, rather than extracting information with a deductive conceptual framework. "Grounding" is how narrative research forms a theory. Clandinin and Connelly (2000) believe that narrative is more concerned with experience, and one of the starting points of narrative inquiry is the researcher's narrative of his own experience. Nelson (2011) emphasized the need for narrative research in language education and teacher professional development. Educational narrative research can make teachers become the real research subjects. It is an effective way for teachers to manage their personal knowledge. It can promote teachers' knowledge reconstruction. It is an effective way to express and communicate educational experience. It is also conducive to the professional development of teachers and the improvement of teaching ability.

The goal of positivist qualitative research is to explain and predict social phenomena by searching for patterns and causal relationships among social constituents. The purpose of qualitative research is to explore the nature behind the object of study. Auguste Comte, the originator of positivist social science, believed that the social sciences should learn from the natural sciences, which emphasize data-based research methods. In terms of research content, Denzin & Lincoln (1994) argued that qualitative research has both the complex, dense, and concentrated "quality" of the matter itself, and the personal mastery and filtering of the researcher.

2.2 Social Learning Theory

Social learning theory was proposed by Albert Bandura, an American psychologist, in 1952. It explores the influence of individual cognitive, behavioral and environmental factors and their interactions on human behavior, focusing on the role of observational learning and self-regulation in triggering human behavior, and emphasizing the interaction between human behavior and the environment. The materials in this study are derived from the intern teachers' reflections on the authentic online Chinese teaching process. The intern teachers' perceptions and behaviors, the online teaching environment, peer-to-peer communication, and the authentic feedback given by Massey University students all have an impact on the teachers' further actions. Social learning theory suggests that there are three mechanisms of individual learning behavior, namely, association, reinforcement and observational learning. Among these, reinforcement contains both positive and negative reinforcement. Reinforcement can be categorized as direct reinforcement, alternative reinforcement and self-reinforcement. Direct reinforcement is when people are influenced by the direct consequences of their behavior; alternative reinforcement is when people also observe the consequences of others' behavior, and this consequence also influences whether and how people do the same behavior; and self-reinforcement is when people's perceptions and evaluations of themselves after their behavior influence their further behavioral performance. Self-regulation in social learning theory refers to an individual's internal reinforcement process, which is the process by which individuals regulate their behavior by comparing and evaluating their plans and expectations for the behavior with the real outcomes of the behavior.

According to Bandura, there are two different processes of behavioral acquisition: one is the process of acquiring behavioral response patterns through direct experience, which Bandura refers to as "learning by response", or learning by direct experience; the other is the process of acquiring behavior by observing the behavior of a model, which Bandura refers to as "learning by demonstration", or learning by indirect experience.

This paper conducts a teacher narrative study through the textual content in post-class reflections, combines social learning theory, analyzes the experiences and lessons learned by trainee teachers in online teaching, calculates the same type of problems and the number of actions taken, summarizes the growth path of teachers, and explores the online Chinese teacher training model.

3 Introduction to Teacher Post-class Reflection

3.1 Recycling of Teachers' Post-class Reflection

A total of 93 teachers participated in the five SCOLT sessions of this research, and 450 post-class reflections were eventually returned, totaling more than 130,000 words.

3.2 Framework of Questions for Teachers' Post-class Reflections

In order to recall the retrospective reflection content, the SCOLT program's post-class reflection form for teachers, guides teachers to select an event that they consider important and worthy of reflection, asking them to describe the event from three main perspectives: what happened in the classroom, what the teacher perceived as the main problem, what action the teacher took and explain the reason.

3.3 Textual Analysis Process of Teachers' Post-class Reflections

The qualitative analysis of teachers' post-class reflections was divided into three main steps. First, a classification framework was developed based on the content of teachers' post-class reflection. For example, in response to the events and major issues that occurred in online communication, this study formed an initial classification framework by classifying the textual content of teachers' reflection into four categories: teachers, learners, teaching and technology. Then, the subcategories under each classification framework were examined and determined, i.e., the text content was further examined, subdivided into subcategories based on the classification framework, and each subcategory was coded and labeled. In the process of labeling, the original classification framework is continuously revised and supplemented until all the contents are covered. Finally, the original framework is supplemented and the results are counted. After finishing the text annotation, the final version of the classification framework is determined by adding annotations to the text content against the determined classification framework. In this process, new categories are found to supplement and enrich the original framework. The annotation results are classified according to this framework, and the percentage of each category in the total number of questions is calculated.

4 Analysis of the Results of Teachers' Post-class Reflections

4.1 What Happened and the Main Problems in Online Teaching

Aiming at the events in online teaching, this study analyzes the text content from four aspects: teachers, students, teaching and technology. The following are the analysis results (as shown in Table 1).

Table 1. Classification of Events Occurring in Online Teaching.

Occurrence Aspects	***Frequency***	***Percentage***	***Occurrence Classification***	***Frequency***	***Percentage***
Teacher	111	19.75%	Failure to explain well	40	7.12%
			Lack of preparation	29	5.16%
			Knowing the students well or not	20	3.56%
			Correcting mistakes	12	2.14%
			Intercultural communication issues	4	0.71%
			Failure to understand students	2	0.36%
			Not paying attention to students' situation in time	2	0.36%
			Less communication in Chinese	2	0.36%
Student	294	52.31%	Student made errors	102	18.15%
			Students fail to understand	84	14.95%
			Poor communication	42	7.47%
			Make progress	35	6.23%
			Student ask questions	19	3.38%
			Making suggestions	5	0.89%
			Students rarely use what they have learned	4	0.71%
			No preview	3	0.53%
Teaching	71	12.63%	Teaching content	42	7.47%
			Teaching plan	21	3.74%
			Teaching methods	8	1.42%
Technical	115	20.48%	Network problems	25	4.45%

(*continued*)

Table 1. (*continued*)

Occurrence Aspects	***Frequency***	***Percentage***	***Occurrence Classification***	***Frequency***	***Percentage***
			Equipment problems	18	3.20%
			Operational problems	13	2.31%
Others				30	5.34%
Total				562	100%

Based on the main issues raised by teachers in the content of the teacher reflection text, the same four aspects of teachers, students, teaching and technology will be analyzed, and the following are the results of the analysis (as shown in Table 2).

Table 2. Online Teaching Main Problems Classification Table**.**

Main Problems Aspects	***Frequency***	***Percentage***	***Main Problems Classification***	***Frequency***	***Percentage***
Teacher	219	39.41%	Insufficient preparation	50	8.77%
			Whether to understand the student	41	7.19%
			Bad spot reaction	28	4.91%
			Insufficient knowledge	21	3.68%
			Feedback	21	3.68%
			English level	21	3.68%
			Lack of online teaching experience	16	2.81%
			Whether to give enough attention to students	12	2.11%
			Speaking speed	9	1.58%
Student	214	37.55%	Language knowledge	104	18.25%
			Negative Transfer of Native Language	35	6.14%

(*continued*)

Table 2. (*continued*)

Main Problems Aspects	***Frequency***	***Percentage***	***Main Problems Classification***	***Frequency***	***Percentage***
			Emotional affect	23	4.04%
			Taking initiative	22	3.86%
			Communication problems	15	2.63%
			Not good enough learning attitude	8	1.4%
			Student personality	6	1.05%
			Bad learning state	1	0.18%
Teaching	68	11.92%	Teaching content	43	7.54%
			Teaching methods	17	2.98%
			Teaching plan	8	1.4%
Tech-nical	51	8.95%	Network problems	22	3.86%
			Equipment problems	17	2.98%
			Operational problems	12	2.11%
Others				18	3.16%
Total				562	100%

Teacher Aspects

Teachers described the occurrence of teacher-side issues in their post-class reflections a total of 111 times (19.75%). Teacher-side issues accounted for a relatively small number of instances compared to teachers' focus on student issues in their post-class reflections. Teachers' problems included 40 instances (7.12%) of failure to teach well. The fundamental problem of teachers' failure to teach well is that they do not have enough knowledge reserves, so they do not have enough knowledge to solve students' problems. In some cases, the teacher's on-the-spot response is deviated. In addition to teachers' lack of knowledge, there were also teachers who believed that the problems were related to their lack of preparation (29 times, 5.16%). For example, one teacher found that the prepared PPT did not have English translation, which caused students to have difficulty in understanding it. The teacher thought it was his own negligence and said he would correct it next time. Teachers who were fully aware of their own lesson preparation deficiencies would have a greater sense of direction in their subsequent communication and preparation for teaching. Self-regulation in sociocultural theory consists of three processes: self-observation, self-judgment, and self-reaction, through which the individual completes the regulation of behavior by internal factors. In the process of reflection, teachers engage in self-observation, self-judgment, and self-reaction. Self-observation can be at the time of a behavior performance or after a behavior performance; the former is called self-awareness and the latter is called self-reflection. Through self-reflection, the intern teacher discovers that the events in teaching originate from the teacher's own problems. Teachers achieve self-growth through post-class reflections. Regarding problems that occurred due to inadequate knowledge of students (20 times or 3.56%), one teacher wrote,

> *"I thought the students had already learned '很多 (many) '. Then I put this as a mastered content in the extension of the new word, but the students didn't understand it. "*

In this case, the teacher did not know enough about the language knowledge that the students already had. Other teachers did not know enough about the students' backgrounds, such as when a teacher inadvertently talked about a student's privacy and suddenly realized that the student might be divorced. Through self-observation and self-judgment, teachers reflect on their own problems.

There were 224 instances (38.42%) in which teachers believed that the main problem was the teachers themselves. Among them, 50 times (8.77%) were problems of inadequate preparation. Subsequently, teachers self-regulate and approach lesson planning more deliberately; 41 times (7.19%) were teachers' inadequate knowledge of students; 28 times (4.91%) were teachers' bad spot reaction; and 21 times (3.68%) each were inadequate knowledge and inadequate English proficiency. By reflecting on the main problems, the intern teachers were able to realize their own shortcomings, prepare more solidly for teaching after the reflection, and supplement their learning and mastery of appropriate knowledge, exercise their ability to respond in the field, and improve their English proficiency.

Student Aspects

There were 294 (52.31%) questions about students in teachers' post-class reflections, including 102 (18.15%) instances of student bias. The high number of references to students' errors in the post-class reflections indicated that teachers were concerned about students' problems in expressing themselves in Chinese. The 84 instances (14.95%) in which students failed to understand the teacher's words were related to the relative inexperience of teachers as graduate students in teaching and their inability to grasp the difficulty of the language and content of instruction. In addition, it was also related to factors such as students' level of Chinese language knowledge or uneven listening, speaking, reading and writing skills. Miscommunication between teachers and students occurred 42 times (7.47%). One teacher wrote,

> *"The student asked the teacher what she liked best, but actually asked what she liked best in the Forbidden City, and the teacher answered her own hobby, resulting in both being somewhat baffled."*

Similarly, student questions (42 items, or 3.38%) were concerned by teachers. One teacher wrote, *"Students ask questions about what situations require '的' and what situations do not require '的,' and the teacher provides a brief explanation for the example sentence of the moment."*

This is an advantage of one-on-one teaching, where the teacher can meet the needs of the students; it also tests the teacher's knowledge base and ability to respond in the moment. Teachers were concerned not only with the questions students asked, but also with the progress students made (35 times, 6.23%). One teacher wrote,

"Students made significant progress in the pronouncing of '去' in this meeting."

The questions students ask or the responses they give are the accumulation of direct experience for teachers, which is an important process for novice teachers to grow into proficient teachers. This is consistent with the emphasis on direct experience in social learning theory. Teachers who have experienced specific teaching situations in their teaching have a particularly deep experience of what kind of feedback and effects their actions have.

There were 214 instances (37.54%) in which teachers' post-class reflections identified students as the main problem. Of these, students' language knowledge was mentioned 104 times (18.25%), again indicating that the language teachers' focus was first and foremost on students' problems in expressing themselves in Chinese. The problem of negative transfer of students' native language was mentioned 35 times (6.14%), mainly focusing on students' problems with pronunciation. In addition, teachers considered that the problems were mainly in students' emotional and affective aspects 23 times (4.04%), and teachers considered that students were taking full advantage of their initiative 22 times (3.86%). It can be seen that teachers are concerned about students' attitudes and initiatives, which have potential influence on their further teaching.

Teaching Aspects

Teachers described the emergence of problems in teaching and learning 71 times (12.63%) in their post-class reflections, which mainly included problems in three areas: teaching content, teaching plan, and teaching methods. In terms of teaching content, some teachers reflected that they prepared too much content, while others wrote,

"I finished all the prepared teaching points, but the time was not yet up."

Some teachers reflected on the mismatch between the content they prepared and the students' needs, e.g.,

"Students want to learn about room types like '卧室(bedroom), 客厅(living room) ......'. But that's not what this lesson is about."

Some teachers reflected that students' needs are not being met, and the content that the teacher has carefully prepared may not be of interest to students. Such direct experience is negative reinforcement for teachers in social learning theory. Some teachers recounted the main content or lesson plan in their reflections and no problems occurred. The main problems responded to the teachers' grasp of the difficulty and amount of content to be taught. Regarding the teaching style, some teachers reflected that they explained too much and gave students too little opportunity to practice.

There were 68 instances (11.93%) in which teachers perceived the main problem to be in the area of teaching. Teaching content, teaching Methods, and teaching plan were the three main issues in terms of teaching content, which were generally consistent with teachers' reflections on the events that occurred in online teaching.

Technical Aspects

Teachers addressed technology-related issues 57 times (9.96%) in their post-class reflections, including network, equipment, and operational issues. For IT-based teaching, the stability of the network is a great concern for teachers because it has a fundamental impact on the smooth running of teaching. One teacher wrote in her post-class reflection,

> *"The network condition suddenly became very bad in this lesson! It caused our lesson to break many times. It became the most unsatisfactory part of the lesson for me for five lessons, more unsatisfactory than my own failure to give correct and effective feedback!"*

It is evident that teaching and teacher emotions were very badly affected by the network problems. Teacher behavior is negatively affected by the technological environment of online teaching, which exemplifies the influence of environment on behavior in social learning theory. Regarding the equipment, the main problems were automatic computer updates, running out of power in the middle of the session, faulty audio, and so on. Regarding operational issues, the focus was on recording and sharing screen operation errors.

A total of 51 (8.95%) of the main problems identified by teachers were related to technology, and teachers took actions on technology 26 times (4.33%), such as reconnecting to the Internet, changing the teaching tool to WeChat, reminding each other to record videos, and using Google Translate for text communication. From the above data, it can be seen that teachers attach great importance to technology aspects when reflecting after class. Social learning theory values the interaction of human cognition, behavior and environment. In the online teaching environment, the technological environment is a fundamental factor in accomplishing Chinese language teaching. For online teaching, a good network environment, problem-free equipment and timely and effective operation are the basic conditions.

4.2 Actions Taken by Teachers and Their Reasons

Actions Taken by Teachers

In response to the incidents that occurred in online instruction and major problems, the faculty took the actions shown in Table 3.

Table 3. Classification Table of Actions Taken by Teachers.

Actions Aspects	*Frequency*	*Percentage*	*Actions Classification*	*Frequency*	*Percentage*
Teacher-student interaction	364	60.66%	Feedback	126	21%
			Timely adjustment	116	19.33%
			Using the medium language	59	9.83%
			Communicat-ing to solve	46	7.67%
			Emotional support	17	2.83%
Teacher	108	18%	Optimized content	53	8.83%
			Improvement after class	36	6%
			Adequate preparation	19	3.17%
Technical	70	11.66%	Leveraging Multimodality	44	7.33%
			Technical manipulation	26	4.33%
Time	32	5.33%	Adjusting the speed of speech	23	3.83%
			Leave more blank time for students to think	9	1.5%
No action				26	3.83%
Total				600	100%

Teacher-student interaction is the main category of teacher action. Of these, feedback and timely adjustment were the categories that accounted for the largest number of teacher actions. Teachers mentioned feedback in their reflections a total of 126 times (21%). A portion of teachers tended to give explicit corrective feedback or instructions to students. Usually, teachers did not completely ignore students' biases, but they tolerated them to some extent in order to teach smoothly and maintain students' enthusiasm for learning. Teachers mentioned providing emotional support to students 17 times (2.83%). Teachers improvise and adjust to the situation a total of 116 times (19.33%). Some teachers would change the content of their lesson preparation according to students' requests, some teachers would adjust the content of the lesson and open new topics during the lesson, etc. A teacher wrote, *"When we could not understand each other, I ended the warm-up before the lesson, digressed the topic and started the formal lesson without spending too much time here and also so as not to affect the mood of the students in the lesson."*

It is clear from the teacher's reflections that the teacher paid great attention to the students' emotions and took care to protect their motivation and self-confidence when making adjustments. In terms of the same type of teacher-student interaction, teachers' attention to communicating with students to solve problems was mentioned 46 times (7.67%). To help students understand, or to explain more clearly to them, teachers borrowed English or other media language 59 times (9.83%). Guided by the principle of teaching in the target language as much as possible, some teachers made a compromise choice of using a mixture of the medium and the target language for explanation. Because of this, many teachers realized that their English language proficiency needed to be improved. This self-judgment and reaction is conducive to teachers' own improvement and to teacher development.

A total of 53 (8.33%) of the teachers' unilateral actions were taken to optimize the content. Some problems could not be solved immediately in class, and in order not to interfere with the normal pace of teaching, teachers chose to improve after class (36 times, or 6%). Before the next online teaching session begins, teachers try to be more prepared for teaching (19 times, or 3.17%).

Two kinds of actions taken by teachers are related to the technology subcomponent of online teaching. One category is when teachers take actions related to technology, 26 times (4.33%), and the other category is when teachers resort to multimodal aids to teaching, which are actions taken 44 times (7.33%). The technical actions were usually taken when technical problems were encountered, while the use of multimodality was usually a choice made by the teachers on their own initiative, such as using pictures and videos to assist teaching. The use of multimodality in online teaching is more direct, convenient and faster than in offline teaching.

Teachers took the action of adjusting their speech speed a total of 23 times (3.83%), while the teachers in the above section considered their speech speed too fast in their reflections on the main problem a total of 9 times. This indicates that even if the main problem was not in the speed of speech, teachers would still buy time for students to think and respond by adjusting the speed of speech. Many teachers wrote in their post-lecture reflections that they spoke too fast and sometimes ignored students' feelings and receptiveness to Chinese. Similarly, teachers would leave extra blank time for students to understand 9 times (1.5% of the time). When teachers adjusted the speed of speech or left more blank time for students, students understood the teacher's words or answered the teacher's questions more smoothly and the teaching went more smoothly, which belongs to the positive reinforcement in social learning theory.

Reasons for Teachers to Take Action

Teachers indicated the following reasons for the actions they took (as shown in Table 4).

For the actions they took, some teachers explained the reasons. The greatest goal of teachers' actions aimed at facilitating students' learning was mentioned 85 times (31.84%). The goal of SCOLT as a language teaching program is to improve students' Chinese language proficiency, especially their oral communication skills in Chinese.

Table 4. Action Reason Classification Table.

Reason Aspects	***Frequency***	***Percentage***	***Reason Classification***	***Frequency***	***Percentage***
Student	174	65.18%	Promote learning	85	31.84%
			Increasing student motivation	24	8.99%
			Meeting students' needs	20	7.49%
			Eliminate negative emotions	19	7.12%
			Understanding students	7	2.62%
			Considering Students' Emotional Emotions	6	2.25%
			Observe students	4	1.5%
			Respecting students' acquisition patterns	4	1.5%
			Considering Students' Levels of Proficiency	3	1.12%
			Change bad study habits	2	0.75%
Teaching	58	21.73%	Limited time	22	8.24%
			No interruption of the course	21	7.87%
			Choose better expressions	8	3%
			Methods for further improvement	4	1.5%
			Effectiveness after action	3	1.12%
Teacher	7	2.62%	Teachers are not sure of the questions or answers	3	1.12%
			Not Aware or Noticing	2	0.75%
			Discovering after the lesson	2	0.75%

(*continued*)

Table 4. (*continued*)

Reason Aspects	***Frequency***	***Percentage***	***Reason Classification***	***Frequency***	***Percentage***
Technical	4	1.50%	Optimizing technical conditions	4	1.5%
Others				24	8.99%
Total				267	100%

Therefore, teachers' post-lesson reflections also focused on this point, and teachers were most concerned with facilitating students' language learning. Meeting students' individual needs to the greatest extent possible is also a point that one-to-one online teaching strives to develop, being mentioned 20 times (7.49%). Providing emotional support for students is also an important starting point for teachers' actions. Teachers expressed their wish to improve students' motivation 24 times (8.99%); eliminating students' negative emotions 19 times (7.12%). Teachers also help students change bad study habits (2 times, 0.75%) in consideration of students' long-term Chinese learning.

In online teaching, teachers usually do not spend too much time on one issue. Teachers mentioned a limited amount of time for each communication a total of 22 times (8.24%). For the overall smoothness of communication, they chose to solve the problem without interrupting the lesson 21 times (7.87%). Reasons on the part of the teacher and technology were lower overall. Teachers were sometimes unsure of the question or answer, not aware of the problem or realized the problem after the lesson in 7 instances (2.62%). The reason for teacher action was to optimize the technology sub-part a total of 4 times (1.5%).

In summary, the significance of teaching reflection is that it focuses on the acquisition, possession, and improvement of practical knowledge in teachers' knowledge structures, unlike the traditional teacher training model that focuses only on the transmission of general knowledge to teachers. Reflecting on teaching encourages teachers' self-observation and self-judgment, which is conducive to teachers' self-development and improvement, thus continuously promoting their self-growth. By reflecting on the teaching process, teachers have a clearer understanding of their own professional growth and a direction to strive for.

5 Conclusion

Reflections on online teaching can help teachers be more prepared to teach online and better handle emergencies that occur during online teaching. Analysis of teachers' post-class reflections in the SCOLT program reveals teachers' thinking, growth, and progress.

Social learning theory emphasizes not only the learning of direct experience, but also the acquisition of indirect experience and observational learning. Although we arranged for the intern teachers to watch teaching videos with each other at the end of the five internships, it would be more in line with the guidance of the theory if it could be arranged regularly during the internship.

Through the qualitative method of teacher narrative research, teacher-oriented practice research is conducive to exploring a teacher training model that is more appropriate to the current international format. This study is conducive to promoting the development of practice teaching, creating a new model of international Chinese language education teacher training, and promoting a closer integration of education and practice at the graduate level. In the long run, it is also beneficial to the development of the international Chinese language education industry.

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On Developing the English Translation Competence of Non-English Majors Based on PACTE Translation Competence Model in the E-learning Era

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Abstract. Translation competence is crucial for both academic and professional success. After exploring the deficiencies in current college English translation teaching, this paper proposes to strengthen translation teaching for non-English majors in college English teaching in the e-learning era, which is also in line with the requirements of Guidelines on College English Teaching. A translation teaching experiment was conducted based on the PACTE translation competence model. The results of the data analysis showed that translation teaching based on this model really made a difference in non-English majors' translation competence.

Keywords: translation competence · translation teaching · PACTE · e-learning era

1 Introduction

English translation competence is one of the most important communicative abilities that college students should cultivate in English learning. In 2006, the module of translation first appeared in College English Test Band 4 and 6. Students were asked to complete the sentences according to the Chinese given in brackets, with a score of 5 points. In December 2013, there was a far-reaching change in the form of translation in CET 4 and 6. Paragraph translation first came to light with a score of 15 points. The paragraph contains about 140–160 Chinese words, covering Chinese history, culture, economy, social development, etc., and emphasizes the learners' comprehensive language abilities. Therefore, it poses great challenges to students while at the same time cultivating their comprehensive English abilities.

At present, we are unwilling to admit that the translation competence of college students is far from being able to adapt to rapid social and economic development. The deficiencies and problems of translation teaching mainly include: (1) neither teachers nor students attach much importance to systematic translation teaching, (2) the teaching model is often too monotonous and outdated, which is mostly typical teacher-centered classes, (3) most teachers pay less attention to translation theories or techniques in general, (4) translation teaching is currently test-oriented, (5) linguistic ability is emphasized

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while cultural knowledge or background knowledge is often neglected (6) teachers lack training in translation teaching, (7) translation teaching is classroom-based only with few computer-based and web-based activities.

2 Previous Research

2.1 Translation Competence

There have been many attempts in defining translation competence. In 1991, Bell regarded it as the knowledge and skills that a translator must possess to carry out a translation [1]. Albrecht Neubert (2000) defined it as a complex set of knowledge and skills that translators need to deal with various topics and texts [2]. Waddington viewed it as a combination of linguistic competence and translating capability [3]. Schäffner defined it as a complex notion that involved an awareness of and a conscious reflection on all the relevant factors for the production of a target text (TT) that appropriately fulfilled its specified function for its target addressees [4]. In 2003, the PACTE group claimed that it was the essential system of knowledge required in translation. In their eyes, translation competence, first of all, is expertise; secondly, it is mostly procedural; meanwhile, it includes distinct inter-related sub-competences; also, it contains a strategic part, which is particularly important. In their model, translation competence consists of psycho-physiological components as well as five sub-competences: bilingual sub-competence, extra-linguistic sub-competence, knowledge about translation, instrumental sub-competence, and strategic sub-competence [5].

2.2 Translation Teaching

For years, translation has been the core of language teaching. Since translation is the communication between languages and cultures, it inevitably involves interaction and cooperation between people. In college English teaching, it should remain its important position as a useful device. According to Duff, translation was one of the basic elements of language in medieval universities and schools [6]. In 1998, Stibbard claimed that translation was a skill whose development should also be included in the teaching plan alongside the other four language skills since it was a universally useful activity, even in monolingual societies [7]. Liu Heping believed that the process of translation teaching was to guide and help students develop corresponding professional or vocational translation skills by employing various methods. He also claimed that the main purpose of translation teaching was to help students understand that most of the equivalent meaning of words was not fixed [8]. Schäffner asserted that in foreign language learning, translation was to reproduce the information of the source text while paying attention to different language structures, a kind of decoding-encoding translation [4]. In 2009, Ran Shiyang pointed out that the main purpose of traditional translation teaching was to develop learners' language ability, which was usually teacher-led and focused mainly on error correction, words or sentences, and foreign language competence [9].

2.3 E-Learning

Education is stepping to a new level with the learners and teachers benefiting from the popularization of computers. With the development of the Internet, experts believe that there is almost no face-to-face teaching because most universities provide online platforms for distance learning students as well as full-time students [10]. Caron held that online courses provide students with a lot of advantages: flexible learning schedules, minimizing the time it took to change physical locations, and promoting interaction between students and professors [11]. It proved to be a feasible alternative to face-to-face teaching [12]. Therefore, e-learning is supposed to be a supplement to other methods, not a replacement for them. It should be used only when it enriches and strengthens what is already being done [13]. Holmes and Gardner also suggested improving the traditional learning environment by integrating e-learning appropriately [14]. In order to ensure efficient online teaching, several conditions are to be met: good Internet access, highly qualified equipment, and professional IT training [15].

3 Methodology

This study was conducted in the fall semester of 2021 as one of the teaching reform projects of NingboTech University 2021. The data serving as support for the assumption were gathered from three freshmen classes in a college English course in the fall semester of 2021, which was a required basic course for undergraduate students. The researcher used to meet the students regularly twice a week and each class lasted for 90 min. There were 16 weeks in this semester. In this study, quantitative and qualitative data were collected and analyzed during the analysis and interpretation process. The purpose of this design was to examine the effect of translation teaching before and after the experiment was carried out.

3.1 Participants

The study was carried out with 104 participants (65 male-62.5% and 39 female-37.5%). The subjects were freshmen, specializing in one of the following disciplines: computer science and technology, industrial design, financial management, electrical engineering and automation, logistics management, and bioengineering.

3.2 Hypotheses

Translation teaching, by employing traditional teaching methods combined with e-learning practices based on the PACTE translation competence model, is supposed to help students develop their English translation competence.

3.3 Procedures of Translation Teaching

Pre-Test

At the beginning of the experiment, students were offered a translation task within 30 min in class, the content of which was from a previous CET 4 test. The aim of the pre-test was to check the students' translation abilities and identify their problems before the experiment.

Classroom Teaching

Materials:

The textbook used for the College English course in this experiment was New College English Book 2 edited by Zhejiang University. The textbook is structured as follows: it contains ten units which are further divided into four parts (part 1-preparation, part 2- reading centered activities, part 3-further development, and part 4-translation and writing).

Translation Teaching Practice:

Based on the PACTE translation competence model, the teaching and learning activities were carried out around the following five sub-competences.

Linguistic sub-competence. According to the PACTE group, it includes pragmatic, sociolinguistic, textual, grammatical, and lexical knowledge [5]. Guidelines on College English Teaching defines College English as a language course that provides basic knowledge of English, whose purpose is to cultivate students' comprehensive ability to use English, in particular, their listening and speaking ability [16]. Throughout the whole semester, language competence was still the main concern of the teacher as well as the students because linguistic sub-competence could lay a solid foundation for translation competence. Based on the New College English Book 2, the comprehensive ability to listen, speak, read, write, and translate were emphasized and tasks were reasonably assigned. In part 1, students were asked to discuss in teams the questions about the topic of the unit. In part 2, students were engaged in reading-centered activities. Reading comprehension exercises, vocabulary exercises, and translation exercises were assigned. Part 3 further consolidates the related knowledge of vocabulary and grammar, helping students improve their comprehensive language application ability.

Extra-linguistic sub-competence. Guidelines on College English Teaching also defines College English as an ability-strengthening course to help students broaden their horizons and understand different cultures in the world. Besides its function as a tool, it also has humanistic values. Hence, when College English courses are designed, it is essential to take into account cultivating students' cultural abilities and teaching different cultural knowledge of the world [16]. It consists of general knowledge about the world, specific domain knowledge, bi-cultural and encyclopedia knowledge [5]. The coursebook, New College English Book 2 covers 10 different topics: love, communication, psychology in our daily life, dreams, food, culture, money, shopping, emotions, and health. In addition to language teaching, cultural and humanistic values were emphasized at the same time. In the preparation part (part 1), the lead-in process offers students background knowledge about the topics of a unit. In the third part, various extended activities help broaden students' horizons and improve their comprehensive abilities.

Knowledge about translation. It consists of knowledge of translation functions and professional translation practice [5]. The more translation knowledge students master, the more confident students will be in translation. Part 4 of the New College English Book 2 systematically introduces translation skills and provides translation practice opportunities. Moreover, when reading-centered activities in part 2 were carried out, translation knowledge was offered at the same time.

Instrument sub-competence. This sub-competence is essential both for academic and professional excellence. Regarding instrument sub-competence, the PACTE group advocated the use of documentation resources and information, and communication technologies applied to translation [5]. Guidelines on College English Teaching also emphasizes the help of dictionaries in its basic, intermediate, and advanced requirements for translation. In the process of translation teaching and learning, it was observed that most of the students frequently used the Baidu search engine, while Baidu online dictionary and Youdao online dictionary are the most popular online dictionaries among students.

Strategic sub-competence. It is crucial because translation is a problem-solving process, which needs strategic power. The PACTE group refers to it as procedural knowledge to ensure the efficiency of the translation process and solve problems that emerged. Its function lies in planning the process and executing the translation projects; evaluating the process and partial results obtained related to the final purpose; activating different sub-competences and compensating for any defects; identifying translation problems and solving them by application [5]. In the classroom, the teacher encouraged student-centered activities in translation practice, which attracted the students' attention and aroused their interest. In the class, time was allocated to allow students to produce their own sentences. For example, after a translation task was assigned, students were encouraged to compare, discuss, and improve their translations in teams.

E-learning Experiences

Guidelines on College English Teaching states the importance of combining online e-learning in college English teaching. As Cairncross and Mannion claimed in 2001, well-designed e-learning resources and activities could improve the learning experience for students in high education at multiple levels. For example, web-based resources and activities could provide opportunities for personalized, autonomous learning opportunities and might promote more flexible participation options [17]. In addition to classroom teaching, an online course on the Welearn platform was used as a supplement to traditional teaching methods. Moreover, communication tools, social computing networks, and blogs also help to create new opportunities for knowledge and information exchange. The research also made use of QQ, We-chat, and Dingding for meetings, discussions, and guidance during the teaching process.

Post-Test

In order to compare the efficiency of translation teaching, a post-test was conducted at the end of that semester. Like the pre-test, students were offered a translation task within 30 min in class, the content of which was from a previous CET 4 test.

4 Findings and Discussions

This section describes the analysis of data collected before and after the test. In order to evaluate the efficiency of translation teaching, descriptive statistics such as mean, standard deviation, and the t-test, were used to find out the results mentioned in the discussion.

Table 1. Assignment result

Pair 1	Mean	Standard deviation	Standard error mean
Pre-test	5.414	1.700	0.167
post-test	7.087	1.475	0.145

Table 1 above is the descriptive statistics of 104 students before and after the test. After providing translation teaching, the scores of 104 students improved compared with the pretest scores. The gap between pre-test and post-tests scores may reflect the impact of translation teaching. The mean value of the pre-test was 5.414 and the standard deviation was 1.700. The mean value of the post-test was 7.087 with a standard deviation of 1.475. Based on these results, the value before the test is lower than the total value after the test, and based on the standard deviation value, the spread of the pre-test is greater than the value after the test which implies more pre-test variation. The average error value for the pre-test value is 1.167 and the average error value for the post-test is 1.145.

Table 2. Paired sample correlation

Pair 1	Number	Correlation	Significance
Pre-test & post-test	104	0.435	0.000

Table 3. Paired sample t-test results of the pre-test and the post-test

Pair 1	Mean	Standard deviation	Standard error mean	T-distribution	Significance (2-tailored)
pre-test & post-test	-1.673	1.700	0.167	-10.05	0.000

According to Table 2, the correlation between the two samples is 0.435, which shows that there is a moderate relationship between the two translation tasks. The significance value is 0.000, which indicates a great difference between the two translation tasks. From the perspective of meaning and value, we may safely arrive at the conclusion that translation teaching has made a great influence on students' translation competence.

The test used to determine the success of translation teaching was paired t-test comparison. The mean and standard deviation of scores for 104 items are shown in Table III. Based on table III, the difference in average before and after translation teaching is -1.673. The standard deviation from the difference between before and after giving translation teaching was 1.700, which was acceptable at the sig level. The value of sig (2-tailed) $0 < 0.05$, indicating a significant difference between before and after the experiment.

According to the samples of students' translations, the survey results showed that most of the students had grammatical problems, and most errors made by the students were interlingual errors, which indicates the influence of the mother language. Grammar is a common problem for students, even though they have learned English for many years in primary and middle schools. It was also noted that when English grammar appeared in the classroom, some students showed an obvious lack of interest. Besides grammar, lack of vocabulary is also the main reason for common mistakes. Many students complained about the lack of vocabulary in translation, while misunderstanding, syntax, pragmatics, punctuation, stylistics, terminology, wording, spelling, usage, verbatim, addition/omission, distortion, and rhetoric are among other common errors.

The evaluation of the teaching quality of the semester also reflected students' overall satisfaction with translation teaching. In the interviews during the teaching process, the students' feedback showed their positive attitudes toward translation teaching and confirmed the important role of translation teaching in cultivating translation competence.

5 Conclusions

The present study explores a problem that challenges non-English majors, which was usually neglected in the past. They lack both theoretical and practical knowledge about translation. Their previous education in this field generally lays emphasis on the products instead of the process. The teaching employs the traditional teacher-centered method and seldom encourages the students' creativity and active participation. In order to reduce students' boredom and encourage their active participation, question and answer activities are carried out and examples are given to make students more active and creative in learning. Apart from this, tasks and activities also include those related to linguistic aspects, such as word selection, grammar, and style; and activities related to cultures, such as proverbs and their equivalents, idioms, and collocations. Through these activities, the level of understanding of each student was monitored.

Generally speaking, the results obtained from this study prove that there are some differences in the students' performance before and after translation teaching practice. However, there are still some limitations in this study, which are worthy of being furtherly explored. First, the number of students tested is limited, therefore, the materials studied can be regarded merely as an illustrative example of materials being used and methods currently being followed. Secondly, the results of the quantitative analysis are only tentative because they may be subjective to a certain extent and only the opinions of researchers are considered. Nevertheless, it is hoped that the present study will serve as a catalyst for further research on the cultivation of translation competence. In addition, it is worth mentioning that teachers have little freedom in choosing the teaching materials and contents to be covered in the class because the syllabus is bound to meet the degree-granting requirements. Finally, students need more tasks, activities, and exercises to improve their translation competence. At the same time, a criterion is essential for the evaluation of students' performance.

With the acceleration of globalization in the 21st century, there is a growing demand for improving translation competence. In today's competitive society, skilled English translation ability is a prerequisite for application-oriented talents. Fortunately, advanced information technology offers more favorable language learning experiences for educators and learners. Network-based e-learning platforms provide important opportunities to enrich the learning experiences for all students in higher education. Therefore, while developing students' translation competence in college English teaching, e-learning practices should be combined with classroom efforts.

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The Roles of Online Chinese Teacher Based on the Advance Organizer Theory

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Abstract. Compared with traditional offline face-to-face teaching, the teachers, teaching textbooks, and teaching methods in online Chinese teaching are different in many aspects. These changes suggested that it is necessary to re-examine the roles and functions of teachers. Beijing Language and Culture University and Massey University in New Zealand have developed a distance learning cooperation program, aiming to stimulate learners' initiatives and Chinese oral skills through one-on-one online oral tutoring. The study adopted the method of empirical research to analyze online Chinese teaching videos. The result showed the multiple roles of Chinese teachers. They are the teaching initiator, the learning tutor, and the communication cooperator who can achieve the goal of helping students adjust their learning state, internalize Chinese knowledge and abilities, and realize meaningful learning. Based on the advance organizer theory, the study explored how proficient teachers, as various roles, adopted different teaching strategies to achieve the appropriate teaching functions. The study may expand the understanding of the role of online Chinese teaching, and provide online Chinese teaching with a broader application prospect.

Keywords: The Advance Organizer Theory · Online Chinese Teaching · Teacher Role

1 Introduction

In the era of "Internet+", online foreign language teaching is showing a new situation of "language-technology-globalization" [1]. The Duolingo Language Report published in 2021 by Duolingo Co. Ltd., showed that learners worldwide continue to turn to languages to build bridges with cultures and people, across distances people can't quite

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traverse in person-yet[1]. Online teaching is becoming one of the major forms in Chinese as foreign language teaching, and a more heterogeneous community of online Chinese learners is forming gradually [2]. Faced with the new situation, it may be difficult for Chinese teachers to follow standardized teaching process and method to meet the needs of online learners. Online Chinese teachers are facing new challenges, for example, Chinese teachers should play multiple roles. Therefore, it is worth studying how Chinese teachers make use of the rules and characteristics of online teaching, orientate their roles and change among different roles comfortably, in order to complete the dual change of teaching concepts and teacher roles.

The Synchronous Chinese Online Language Teaching (SCOLT) program is developed by the research institute of international Chinese Language Education at Beijing Language and Culture University (BLCU) and the Joint Research Centre of the Faculty of Humanities and Social Sciences at Massey University in New Zealand. It is a micro-Chinese tutoring program in addition to the systematic Chinese circumstances in New Zealand [1]. The program has been conducted a total of five times for each period, with every lesson lasting 15–20 min, with the goal of improving learners' oral Chinese language skill. In the micro-lesson, the learners are adults in New Zealand who are studying a Chinese circumstance together but have significant differences in their Chinese learning backgrounds and Chinese proficiency. Due to the constraints of the learners' different schedules and other factors, they are unable to complete the local Chinese circumstances. Meanwhile, they have special needs for Chinese learning based on their careers and identities, which are difficult to meet under regular circumstances. Thus, they wish to get additional personalized Chinese tutoring. The teachers are proficient teachers from BLCU, who have rich traditional and online experience in teaching Chinese. Analyzing the teaching records of these proficient online Chinese teachers contributes to deconstructing the multiple roles and functions to provide practical references for how teachers can achieve meaningful learning through multiple roles.

2 Theoretical Foundation and Related Studies

2.1 The Advance Organizer Theory

The advance organizer theory was proposed by Ausubel [3]. The theory argues that it's necessary to provide the built-in highlights of crucial information to activate the learners' prior experiences, aiming to provide the learners with a stable cognitive structure upon which new knowledge can be anchored [4]. In addition, the advance organizer theory is supported by the meaningful learning theory, which shows the inner workings of advance organizers. Learning is enhanced when superordinate, representational, and combinatorial process occur during information comprehension so that learners can find meaning in the new information [5, 6]. Based on the advance organizer theory, Joyce, Weil and Calhoun [7] proposed three teaching stages. In the first stage, the teachers activated the information related to the new knowledge in the cognitive structure of the learners by

[1] Duolingo Homepage, https://blog.duolingo.com/2021-duolingo-language-report/, last accessed 2023/3/2.

showing advance organizers. In the second stage, the teachers used the advance organizers to build a bridge between the new knowledge and the learners' original cognitive structure. In the third stage, the teachers presented the new advance organizers to continuously improve the learners' internalization level of the new knowledge and extend the learners' thinking space. It indicated that in different teaching stages, teachers' tasks are different, and their preference for the advance organizers are also different.

The functions of the advance organizer theory are maintaining and facilitating learning [8]. The functions in terms of facilitating learning can be further divided into three situations. (1) Activating learners' known knowledge related to new knowledge [9]. (2) Acting as a bridge between new and known knowledge [10]. (3) Creating new situations and transforming new knowledge [11].

The relevant studies of foreign language teaching have shown that advance organizers have an influence on foreign language skills teaching, learners' perceptions of self-efficacy, and teacher role orientation. For example, Karakuzu and Akdemir [12] conducted an empirical study on the role of video as an advance organizer in the teaching of listening and speaking skills, they found that video played an important role in learners' recall and retention of language material, which concluded learners' oral output. Besides, Hasirci Aksoy [13] reported the effect of advance organizers on learners' perception of self-efficacy. And Thibodeau [14] found that advance organizers could influence learners' perceptions of teachers, it affected teachers' role orientation.

The studies have demonstrated that the advance organizer theory can be used to guide foreign language teaching. However, the advance organizers can only be effective if they are scientifically selected, designed and presented to learners appropriately. Therefore, advance organizers not only connect new knowledge with known knowledge but also connect the teachers with the learners.

2.2 Research on the Role of Online Foreign Language Teachers

Weng [15] has recognized the "complexity" of online teacher roles and suggested that it's mainly reflected in the "multiplicity". The multiplicity of teacher roles can be found in terms of their teaching functions. Feuerstein [16] viewed online foreign language teachers as "facilitation variables", and Kong [17] classified the roles of online teachers as guides, collaborators, and supporters, depending on the ways of facilitation. Goldstein and Simka [18] suggested that the core function of teachers is moderating. The studies showed that the multiple roles of teachers could be divided into three types. (1) The initiator of teaching. (2) The cooperator of communication. (3) The tutor of learning.

Based on the advance organizer theory, the study attempts to provide a detailed description and analysis of the roles of online Chinese teachers. The study intends to answer the following two research questions.

- Based on the advance organizer theory, what are the possible roles of online Chinese teachers?
- What are the characteristics of teachers' behaviors in different roles? What are their functions in teaching?

3 Online Chinses Teacher Roles Orientation in SCOLT

In SCOLT, in the process of facilitating learners' internalization of language knowledge and ability, the teachers are responsible for the language teaching initiator, the language communication cooperator and the language learning tutor. Different teacher roles will lead to different forms, contents, and functions of advance organizers.

3.1 As the Language Teaching Initiator

Isman and Dabaj [19] suggested that teachers are the main communicators for establishing teacher-student interaction in online teaching. The SCOLT takes oral language skills tutoring as the main teaching goal. Since the lesson time is limited to 15–20 min, teachers should focus on the teaching goals and become the initiator of language teaching. Therefore, teachers should know the learners' profiles in advance and formulate key points in the target language during lesson preparation, and prepare materials related to key points in the target language before the lesson. Now, the advance organizers are mainly in the form of pictures, videos, and other multimedia. The contents are mainly about a topic related to the learners' identity and life. The function of the advance organizers is to remind learners to recall known knowledge related to the topic and consciously guide them to organize their discourse toward the language's key points. It facilitates learners successfully use the target language in a concrete and vivid context to express themselves and achieve meaningful learning (as shown in Example 1).

Example 1

T: 我想给你看一个图片, 好吗? I want to show you a picture.
S: 好.
T:这是什么?
S: 生日蛋糕, right!
T: 对, 有谁? Can you introduce what happened in the picture?
S: Uh, 妈…妈妈有2个儿子, 1个女儿.
T: 嗯!
S: Uh, 妈妈有生…生日, 妈妈, 妈妈的生日.
T: Uh, 今天是妈妈的生日.
S: Yeah, uh, 她有生日蛋糕.

In Example 1, as the Chinese teaching initiator, firstly, the teacher has prepared a picture of a family birthday before class to remind the learner of her life experience and known Chinese language related to the topic of family members and birthday. The teacher also created a typical context in which 有 means "have" and suggested related words (e.g., 生日蛋糕). Secondly, with the question "有谁" Can you introduce what happened in the picture?", the teacher guided the learner to realize that she should use 有 to match have. Finally, the learner accurately said "妈妈有2个儿子, 1个女儿" and "她有生日蛋糕", which showed that the learner has successfully acquired 有 and internalized its meaning.

3.2 As the Language Learning Tutor

In SCOLT, sometimes, the teachers do not use the prescribed textbook to meet the individual learning needs of learners so that they can flexibly organize and choose the teaching content. Meanwhile, the absence of textbooks makes the teachers as the role of language learning tutors prominent, as the teachers are the main reference standard and source of feedback for the learners in the process of learning spoken Chinese. The teachers usually introduce topics related to the learners' life and work, and the advance organizers are words related to target language points. The role of language learning tutor helps learners to internalize the target language smoothly (as shown in Example 2).

Example 2

S: 我的两个女儿学中文.
T: 嗯!
T: 你跟女儿说汉语吗?
S: 我的大女儿写汉字, 说汉语.
T: Oh, 写汉字.
S: 我的小女儿, 学…说中文, 没有写汉字.
T: Oh, 不写汉字.
S: Yeah, 不写汉字.
T: 你和女儿一起说汉语吗?
S: 对对对, 我们都说中文.
T: 很好, 很好! 你的女儿说汉语, 你听得懂吗?
S: 啊?
T: 听得懂吗?
S: What's 听得懂?
T: 听, listen. 懂, understand.
S: 哦, 大女儿…
T: 嗯?
S: 听得懂.
T: 嗯.
S: 啊, 小女儿还好.
T: 还好, haha.
S: A little bit.

Before Example 2, the teacher had learned that the learner's two daughters were also learning Chinese. The teacher then used the topic of learning Chinese as the advance organizer to test whether the learner has acquired the resultant complements or not. After repeating the question "听得懂吗?", the teacher found that the learner could not understand the meaning of the sentence. Then the teacher used the word explanation in the learner's native language as the advance organizer to help the learners understand the meaning of the sentence. During the process, the teacher also showed the learner the gramma of the resultative complement in the discourse. The teacher played the role of language learning tutor. Based on the learner's subsequent response, the learner has successfully understood the grammatical meaning of the resultant complement and could answer the teacher's question appropriately. It is indicating that the learner has achieved meaningful learning.

3.3 As the Language Communication Cooperator

As the micro- complimentary course to the systematic school curriculum, the SCOLT has the function of meeting individual learners' needs. When teachers are confronting learners who have clear learning needs and are willing to express themselves actively, the teachers often play their roles of the learners' communication cooperators. By analyzing the teaching record, it showed that when the teachers play the role of language communication cooperator, the teachers may not forecast the target language point. They usually observe the learners' errors in phonetics, vocabulary, grammar, and others in communication processes to find the problems encountered by the learners in the process of learning Chinese. After that, the teachers conduct individualized tutoring according to the learners' identity and learning ability. Therefore, the teachers mostly use oral Chinses to show advance organizers. The content of advance organizers is often related to the target language points, which could help learners build a bridge between given and new information (as shown in Example 3).

Example 3

T: 今天你想说什么?
S: Uh…今天我想说 location.
T: 地方, 对, 地方.
S: 地方, Does that mean location?
T: 嗯嗯, 好.
S: 啊, like旁边, 对面…
T: 对.
S: like 左边, yeah.
T: 对, 在…地方.
S: Uh, ok, so all of them, haha.
T: 好, 好, 没问题, 没问题.

Example 3 occurred at the beginning of the 3rd tutorial lesson. Since the teacher had communicated with the learner in the prior two lessons, the teacher knew that the learner was willing to express herself and had clear learning goals. Therefore, in the third lesson, the teacher did not show advance organizers to the learner, and the teacher's questions were not intended to trigger a certain topic. The teacher played the role of language communication cooperator to discuss the lesson's learning goals with the learner so that the learner would automatically trigger related advance organizers about new knowledge. As shown in example 3, the learner said, "想说 location" and recalled the words related to location (e.g., 旁边, 对面, 左边), which laid the foundation for the following Chinese locative expression.

4 Realization of SCOLT Teacher Role Function

Based on the advance organizer theory, the study investigated the teaching process in SCOLT, and found that the teachers performed motivating and scaffold functions. The motivating function mainly showed how the teachers utilize the advance organizers to guide learners to achieve different learning goals. The scaffold function especially showed how the teachers correct learners' errors. Meanwhile, if the roles of teachers are different, they present distinct differences in the process of achieving the functions. However, regardless of the role of teachers, they followed the requirements of advance organizer theory and made beneficial use of the mechanism of advance organizers. Finally, they achieved the goal of SCOLT to improve learners' Chinese abilities.

4.1 Implementation of Language Teaching Motivating Function

In SCOLT, different teaching goals remind teachers of choosing different teacher roles to achieve corresponding functions. The investigation found that although teachers played multiple roles, they all followed the mechanism of the advance organizer theory, and finally completed the teaching goal. The following examples showed distinct roles of teachers, namely language teaching initiators, language communication cooperators and learning tutors. It also showed how teachers could effectively provide learners with different contents as the advance organizers and achieve the motivating functions (as shown in Examples 4–5).

Example 4

T: 你好吗?
S: 我很好, 你呢?
T: 我也很好, 你忙不忙?
S: 忙, 我很忙, 我的儿子…打篮球了.

Example 4 took place at the beginning of a lesson. Now, the teacher's goal was to shorten the mental distance so that the learner could express herself naturally in Chinese in an open and relaxed environment. Therefore, the teacher played the role of language communication cooperator to see the recent situation of the learner through daily greetings. The teacher made the learner go into the learning state naturally and created an atmosphere that helped learners achieve meaningful learning. In the following Example 5, the teacher, as the language learning tutor, used advance organizers to motivate the learner to internalize target grammar.

Example 5

S: 我快, 我开车, 我快开车.
T: 哦!
S: I…I have to drive it fast, so 我…I don't have a word to say that…, 我出家快开车?

T: 哦, 我回家开车开得很快.
S: Say that again, please!
T: Yes! If you want to say you do something quickly, you should say 开车开得很快.
S: 啊, ok, 开车开得很快.
T: 对, 开车开得很快, I write down that for you. Maybe you need…
(白板: S + V + 得 + Adj)
T: So, you can say我开得很快.
S: 我开得很快.
(白板: S + V + N + 得 + Adj)
T: 开车开得很快. For you, the adjective could be "好".
S: 我开车开得很好.

In Example 5, as the role of the language learning tutor, the teacher's goal was to help the learners express the meaning of the degree complement by using the sentence S + V + N + 得 + Adj. The teacher started with the learner's error and made it as the advance organizer to show the learner the correct form of the language, e.g., 我回家开车开的很快. When the teacher found that the learners did not understand the sentence in time and asked the teacher to repeat it, the teacher first explained the meaning and simplified the sentence to S + V + 得 + Adj and used the whiteboard to show the form of the grammar to the learner in written form. When the learner repeated it correctly, the teacher added the noun between the verb and "得" to help the learner understand the grammar form and meaning accurately step by step. From the learner's response " 我开车开得很好", it could be inferred that the learner had successfully internalized the structure and meaning of the grammar because she could use the sentence S + V + N + 得 + Adj to express other purposes instead of simply repeating the teacher's sentence. Next, the teacher played the role of language teaching initiator to motivate the learner to reinforce understanding of new knowledge by showing new advance organizers (as shown in Example 6).

Example 6

T: 嗯, 好, 你的儿子打篮球?
S: 对.
T: 他打篮球打得好吗?
S: Oh, 还好.
T: Haha.
S: 啊, 他打得还可以. Is "还可以" means "it's average"?
T: Yes, average.
S: Not the best, not the worst.
T: Yeah, 对, and you can say他打篮球打得还可以.
S: OK!
T: 嗯!他…
S: 他打篮球打得还可以.

In Example 6, the teacher's goal was not to show the new knowledge but to reinforce the learner's understanding of the new knowledge through practice. Therefore, the teacher should play the role of language teaching initiator to show the learner new advance organizers. From the teacher-student conversation, the teacher has found that the learner's son has a hobby of playing basketball and the learner is a stay-at-home spouse who also often needs to pick up her son to basketball games. Therefore, the teacher used the topic of the basketball hobby son as the advance organizer and asked the learner "他打篮球打得好吗?", which reinforced the learner's understanding of the grammar form and meaning.

4.2 Implementation of Language Acquisition Scaffold Function

The advance organizer theory emphasized meaningful learning, and Ausubel (1969) suggested that the process of meaningful learning is the process of establishing a substantial connection between new knowledge and the learners' cognitive structure. The connection is not random but is based on a logical foundation. Therefore, the different roles of teachers in achieving the scaffold function should implement differentiated teaching strategies according to the different errors of the learners (as shown in Examples 7–8).

Example 7

T: 啊, 你来过中国, 对吗?
S: 啊, 我来过中国.
T: 嗯.
S: 两次.
T: 什么时候?
S: 啊, 差不多五年前, five years ago. 啊, and 今年, 7月.
T: 嗯.
S: 我和我的女儿, 出国厦门.
T: Oh, 厦门.
S: 厦门, 我们喜欢厦门.
T: 嗯! 厦门天气怎么样?
S: 啊, 厦门天气很热, 我们喜欢, 天气很热, 很舒服.

The teacher played the role of language teaching initiator in Example 7. The topic of travel to China is the advance organizer. The teacher, as the inspirer of language teaching, focused on the topic of travel to China as an advance organizer to initiate the learner's discussion about the weather. Therefore, the teacher did not strictly correct each of the learner's language errors when they were not related to the target topic and did not affect the meaning of the expressions. For example, the phrase "出国厦门" is an error caused by the negative transfer of the learner's native language, and the corresponding expression in English is I went abroad to Xiamen. In English, the corresponding expression is I went abroad to Xiamen. There is no verb in English between broad and Xiamen, only the preposition to which indicates the direction, so the learner misses the verb "去". The correct expression should be "出国去厦门". If the teacher had explained this error in detail, firstly, it would have taken a long time, and the whole course would have lasted only 15–20 min. The learner's time to express himself/herself in Chinese would have been compressed. Secondly, it is not related to the target topic. Going abroad to Xiamen is not logically and substantially related to the topic of weather. Strictly correcting errors will lead to deviation from the teaching goal and prevent meaningful learning. Therefore, when the teacher took the role of a language educator, the main purpose was to stimulate the learner's known knowledge related to the new knowledge. The teacher avoided distracting the learner's attention from the target language point by adopting a non-correction strategy for errors that were not associated with the new knowledge and did not affect comprehension. However, in Example 8, the teacher's attitude toward the learner's errors changed a lot. (As shown in Example 8).

Example 8

T: 厦门天气比新西兰热吗?
S: 厦门天气, 热, 比新西兰, that's right? Oh no, 我想说, It's hotter than New Zealand.
T: Oh, 比新西兰热.
S: Yeah, 比新西兰热.

In Example 8, the teacher asked, "厦门天气比新西兰热吗?" to show learners the grammatical form of the comparative sentence. The teacher's role has changed to the language learning tutor, and the teacher's focus has changed to whether the learner could correctly output the grammatical form of the 比 sentence. Therefore, when the learner said "热, 比新西兰", the teacher corrected the learner's syntactic errors by saying "比新西兰热" so that the learner would pay attention to the form in Chinese, the object being compared should be after the preposition "比". The grammatical rule is different from the comparative sentence in English. The teacher achieved the language acquisition function. The teacher's attitude towards error correction is quite different for the same negative transfer of the learner's native language because the rule is logically and substantially related to the target. The teacher should help the learner avoid errors in time to avoid fossilization in interlanguage. Therefore, when the teacher's role is different, the teaching strategy is different in achieving the scaffold function.

5 Conclusion

Based on the investigation of SCOLT teaching records, this study sorted out the multiple roles of expert Chinese teachers in online Chinese teaching in the first place. In the process of helping learners internalize Chinese language knowledge and improve their Chinese expression skills, teachers take on three roles, including the initiator of language teaching, the tutor of language learning, and the collaborator of language communication. Depending on teachers' different roles, the form, content, and dominant function of the advance organizers may also vary.

Second, from the perspective of the advance organizer theory, the study analyzed the teaching strategies with different role orientations to achieve the motivating function of language teaching and the scaffolding function of language acquisition. The distinct teacher roles and various teaching strategies followed the mechanism of the advance organizer theory and successfully achieved their functions. Therefore, teachers should follow the advanced organizer theory, which is helpful to facilitate learners' meaningful learning.

Isman [20] claimed that online teachers' role awareness should be deeply rooted in the teaching philosophy to design effective online teaching courses. The study can not only help online Chinese teachers clarify their multiple roles and functions to help the learners internalize language knowledge and abilities, but also provide insights for the training and development of online Chinese teachers.

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Development of Teaching Materials Based on Bloom's Taxonomy

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Abstract. Professional courses can identify student-centered teaching goals based on Bloom's taxonomy. However, how to achieve these goals cannot be directly provided by the famous model. This paper shows the construction and application of hierarchical teaching-learning materials (TLMs) for learning, practice, and creation based on Bloom's taxonomy in the Computer System course. These TLMs can effectively help students achieve their learning goals at all levels. At the same time, the actual and rich data brought by students' application of these TLMs can help teachers understand the actual teaching effectiveness in real-time and provide reliable data support for continuouscurriculum reform.

Keywords: TLMs · Bloom's taxonomy · Student-centered · Learning · Practice · Creation

1 Introduction

In the process of undergraduate teaching, it is very important to set teaching objectives for the course. Bloom's taxonomy provides a good basis for the determination of teaching and learning objectives, especially for professional curriculum teachers to set high-level educational goals of specialized courses [1]. It is conducive to evaluate if the courses are really centered on student learning outcome to improve students learning effectiveness [2]. But in the Bloom's taxonomy there are not any proposals how to achieve those goals at every level.

We believe that achieving these goals of student learning, especially for advanced learning ability, requires to carefully design and plan in each course according to its own features. Computer System is one of the most important core-specializes-course for computer majors in Hunan University. It occupies a critical position in the entire specialized design ability and system thinking ability of the training system [3]. Based on the Bloom's taxonomy, we have formulated the teaching and learning objectives of this course, and more importantly, designed and developed a corresponding hierarchical teaching-learning materials (TLMs) system to meet the objectives of different levels. In the teaching process, these TLMs strongly support the implementation of the course teaching. And at the same time, these TLMs obtain real students learning data during the

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use process, so that whether students achieve the corresponding teaching goals has data support, which can provide strong support to evaluate the effectiveness of the teaching and the optional solutions of continuous improvement of the course.

2 Current Status

Bloom's taxonomy, which was named after educator Benjamin Bloom, is a set of hierarchical models used for the classification of educational learning objectives into levels of complexity and specificity. The famous model divides cognitive activities into six levels from low to high: to remember, understand, apply, analyze, evaluate, and create (see Fig. 1).

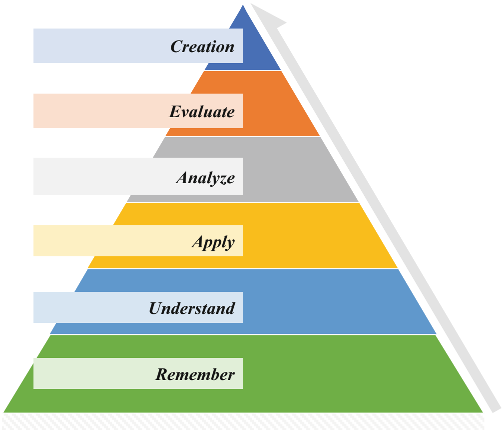

Fig. 1. Bloom's Taxonomy

For professional courses in universities, the course objectives are mostly around high-level application, analysis, evaluation, and creation. It can be said that according to Bloom's goals, to achieve student-centered, measurable, attainable, and clear goals for course instruction is extremely beneficial.

However, Bloom's taxonomy only gives these goals but does not give the process or method to achieve the goals [4]. And for different disciplines or curricula, the goal to be achieved may be different, and the methods and ways to achieve the goals at the same level must also be different. Therefore, although there are hierarchical goals oriented given by the Bloom's model, how to achieve the goals must be adaptively explored for different majors and courses.

3 Computer System Hierarchical Goals

Students should have studied Programming Design and Digital Logic before starting Computer System. Then other advanced specialized courses, such as Operating Systems, Compilation Principles and Computer Architecture, will follow our course. Computer System is a critical hub in the specialized training system of computer knowledge and ability. It also provides students with a broad cognitive perspective of the computer professional field. The teaching content of this course includes more than 200 knowledge points, and we have the targets of the primary cognitive category, such as being able to describe how data and instructions are stored in binary at the "memory" level; or the "understanding" level, comparing machine-level representations of different data types; we also have higher-level learning requirements, such as "application" level, choosing which kind of jump mode can get the fastest response, or "analysis" level, without considering the algorithm, what are the available ways to improve program performance, and what is the best way to do it in a particular scenario? It also includes the "evaluation" level, to assess a programming example whether its locality is good, and then at the "creation" level, what are the ways to obtain good locality code? Even for a certain knowledge point cluster, there are relatively low-order learning objectives such as "being able to describe the basic content of the stack frame", as well as relatively high-order learning objectives such as "analyzing the changes in the stack frame content of the caller and the callee during the call of the recursive function".

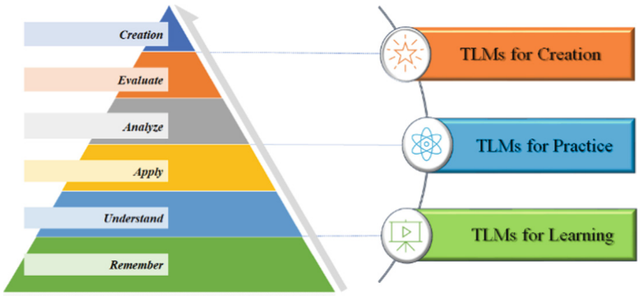

Fig. 2. The Hierarchical TLMs

On the one hand, this course is based on Bloom's taxonomy to set clear teaching and learning goals of each knowledge point or knowledge clusters; on the other hand, with the help of information technology, we have built a variety of TLMs to help students to achieve the different learning goals. These TLMs, corresponding to the levels of Bloom's taxonomy, can be divided into three levels, which include TLMs for learning, practice, and creation (see Fig. 2).

4 TLMs Construction

The construction of teaching resources (platforms) includes learning materials, practice materials and creative materials which are developed by us, and joint developed with existing platform. However, each kind of TLMs is planned and designed closely around students' needs to achieve the corresponding level of teaching and learning objectives.

4.1 TLMs for Learning

This kind of teaching resources construction focuses on the relatively low level of "remember" and "understand" in Bloom's cognitive model. Students are expected to recall the basic and specific concepts, terminology, ways and means, as well as interpretate the meaning of information and materials. We believe that comprehension and memorization go hand in hand, and that a solid memory can be based on comprehension, and a clear memory can lead to a clear understanding. This part of learning content, for beginners, is the actual basis of the upper-level teaching and learning objectives. If the objectives of this part are not well achieved, the higher objectives of the above levels may become water without a source, tree without roots.

Construction Content. We build this kind of TLMs from two aspects: More than 100 short teaching videos have been produced, and the total time is more than 1500 min. These video clips are designed and made to explain the knowledge cluster set in depth. Every video is roughly around 15 min, very suitable for students to use fragment time to browse repeatedly, which is also an important pre-study or review material for traditional classroom teaching.

Additionally, we augment these video clips with knowledge tags, which include forward and follow-up knowledge point-oriented tags, mapped to the course teaching content mind map. This approach enables students to begin their learning journey from any video clip and extend their learning seamlessly. By linking knowledge points into a line and then into a network, students can achieve a personalized learning path.

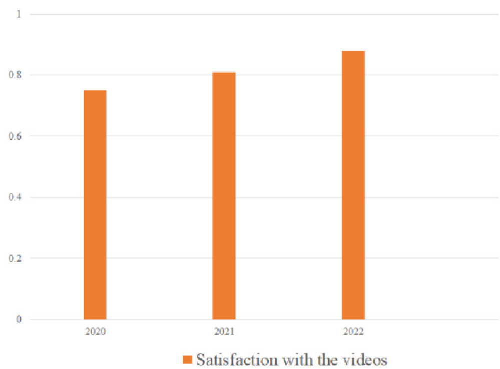

Fig. 3. The Students' Satisfaction with Videos

Application Effectiveness. The short teaching videos have gained enthusiastic attention from students as soon as their launch in 2020. Without the mandatory requirement of viewing the videos as part of GPA, the total viewing time of these video clips reached 921 min per capita each semester, while the course benefits more than 330 students every spring. These short instructional videos have also been well received by students in the post-class student feedback questionnaire (see Fig. 3).

We also observed some intriguing situations. We noted that the video playback rate of the corresponding in-class learning content increased before and after class. This indicates that, consistent with our expectations, students are using these videos as pre and review material. Moreover, some of the videos that had higher total viewership also provided explanations for difficult concepts. However, it is also observed that some of the videos with higher viewership were unexpected and centered around explanations that did not align with the examples used in class. This observation indicates that students are responsive to differences in course learning content and that diverse examples hold significance for their understanding. Then in our classroom instruction, we make it a practice to prepare a minimum of two sets of explanations for challenging concepts. This approach ensures that we have a range of strategies to help students grasp difficult points effectively.

4.2 TLMs for Practice

As Confucius said: it is a pleasure to learn and practice often. This kind of TLM can consolidate what has been learned in class corresponds to the relatively intermediate level of Bloom's model. The TLMs used in our course for application and analysis development comprise of well-designed post-lesson exercises and programming drills. Through these exercises, students are encouraged to solve new problems or respond to concrete situations that have a single or best answer. Programming exercises, in particular, enable students to apply their learning to specific problem-solving scenarios and arrive at optimal results. Our course practice emphasizes the complementary nature of both application and analysis.

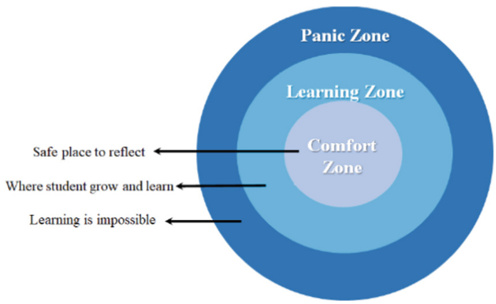

Fig. 4. The Learning Zone Principle

Construction Content. We have designed and developed a parametric intelligent assignment system. Parameterized compose paper issuance, i.e., using the student's login number and time as random numbers, generates parameters in each question. Then every student can get their different practice questions, which can help effectively curb mindless copying among students and encourage them to complete independently. At the same time the difficulty weight is set for each question, which is based on the learning zone model [5] (see Fig. 4), and the different difficulty weight is set for each composing of questions. Then if a student makes mistake in current practice, another practice paper will be re-grouped under the current difficulty weight setting. If there is no mistake, the difficult weight will be adjusted upward to compose another new practice paper for students to do further practice (see Fig. 5).

In addition, we have developed an online automatic code evaluation system on the CG platform, allowing students to solve real-world problems through programming and submit their code for automatic assessment. This system provides students with prompt feedback on the efficiency and quality of their programs, allowing them to make improvements in a timely manner. Furthermore, teachers can monitor student progress through the system, gaining insight into how students are completing programming assignments and assessing overall learning outcomes. Additionally, students can perform self-evaluation and self-reflection through completion rankings.

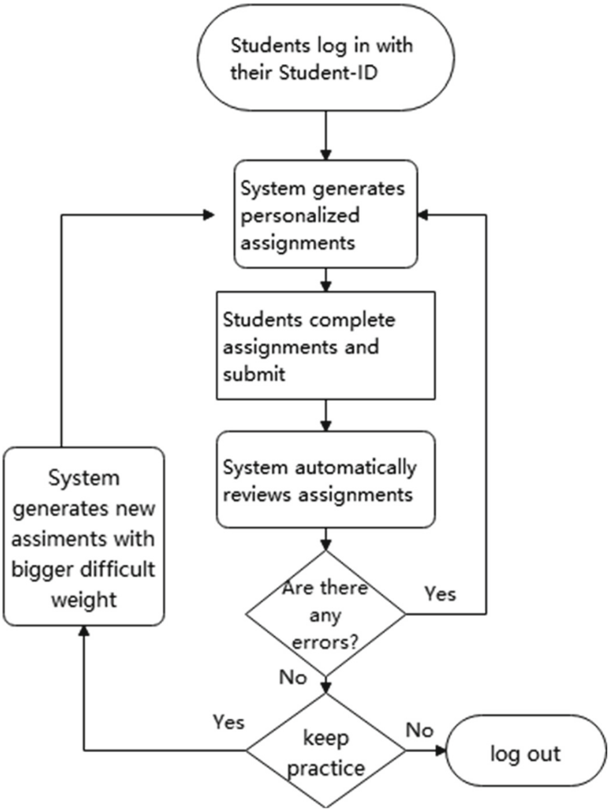

Fig. 5. Students' Practice Process in Parametric Intelligent Assignment System.

Application Effectiveness. The parametric intelligent assignment system plays a crucial role in our daily afterschool homework. Unlike traditional pencil assignments, the backend data of the system shows that, on average, each student made at least 3.2 advanced attempts per assignment, demonstrating a desire not only to achieve perfect correctness but also to challenge themselves with high-difficulty exercises. Additionally, the CG code self-assessment system has seen a growing number of students choosing to remain within the practice system and engage in additional programming exercises (see Fig. 6). This practice has led to significant improvements in their programming skills over time.

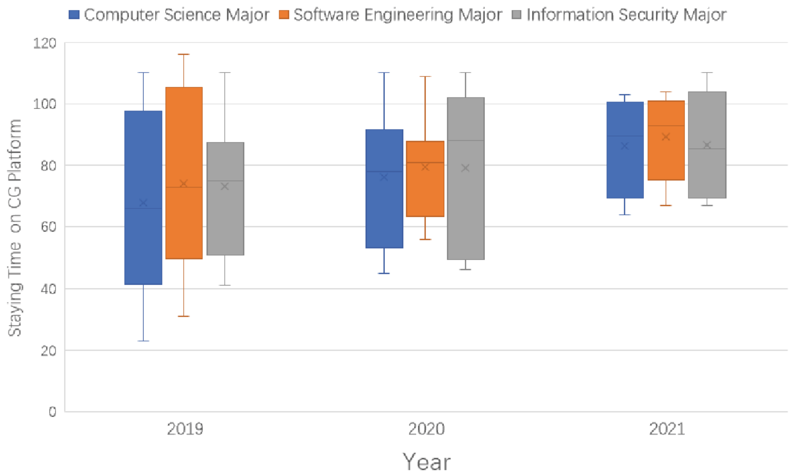

Fig. 6. Comparing Staying Time on CG Platform among Different Majors Students in the Last 3 Years.

The effectiveness of students' learning cannot be solely judged based on their exercise scores. The selection of exercises with varying difficulty weights, as well as the extent to which they are willing to try and optimize their work, provides insight into the different self-requirements and study habits of students. This helps us to identify those who are more actively engaged in the learning process versus those who may be more passive. High-scoring active learners are invited to participate in disciplinary competitions or to join research teams at an early stage, while active learners with low scores receive individual coaching to improve their study methods. For negative learners with high scores, we provide additional encouragement and monitoring, while negative learners with low scores are considered "early warning" students, and receive one-on-one support from teachers and teaching assistants.

4.3 TLMs for Creation

The construction of this kind of TLMs corresponds to the higher-order goals of "evaluation" and "creation" in Bloom's hierarchy model, which are the ultimate goals of undergraduate education. Our students are expected to apply prior knowledge and skills in new and creative ways, and produce an end product that fulfills a given purpose, rather than simply being right or wrong. In our courses, the product may be the result of programming practice, or it may be a proposed solution to a relevant industrial problem. We believe that creative problem identification and solution finding can only be achieved by learning how to evaluate and interpret solutions from diverse perspectives and with varying criteria.

Construction Content. We construct TLMs for creation from two aspects: a progressive experimental system and group discussion topic selection. These aim to develop students' hands-on problem-solving skills, as well as their collaborative communication and presentation skills.

A Progressive Experimental System. In terms of hands-on practice, we have designed a progressive experimental system (see Fig. 7) for our students.

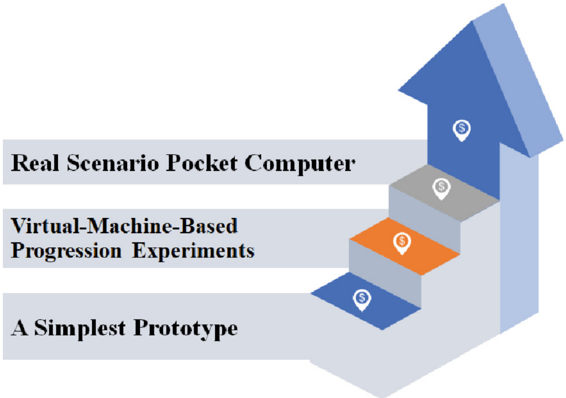

Fig. 7. The Progressive Experiment System.

A simplest prototype is implemented by software simulation. Students can try to experience the data interaction between registers and memory, the correspondence between C code and compiled assembly language, and the initial explanation of the process of storing or running data and instructions at the machine level in this prototype with only 8 basic instructions.

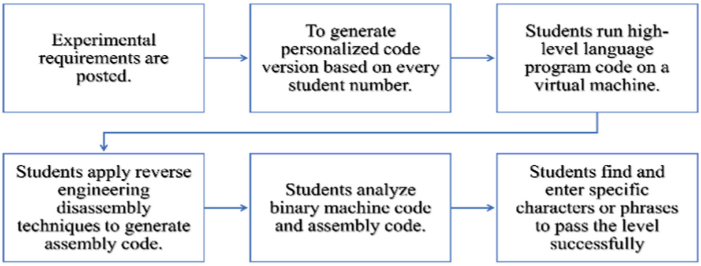

Fig. 8. The Procedure of Students' Completing the Progression Experiments

A series of virtual-machine-based progression experiments are designed, in which students select an appropriate and effective reverse engineering technique to evaluate assembly code, deduce solutions to various tasks, and summarize their work (see Fig. 8). These level-up experiments, with an incentive mechanism similar to that found in games, greatly stimulate students' enthusiasm to continuously explore and solve these experiment problems.

We also have designed a pocket computer (see Fig. 9) with our own intellectual property rights, which enables students to design effective solutions, program and implement them, and evaluate the performance of different solutions in real-world application scenarios to enhance their learning and practical skills.

Fig. 9. The Pocket Computer

Discussion Topics Stem from Industry-Research Collaboration. In terms of comprehensive competency development, we have established partnerships with companies such as Huawei and STMicroelectronics. Drawing on real industry research cases, we have developed a series of selected topics for students to engage with. Working in groups, students select and discuss these issues, evaluating and summarizing different solutions. Figure 10 shows the implementation process of our discussion classes. Video recordings are made of these group discussions, which can be shared and watched among students, facilitating cross-evaluation and interactive learning. This approach helps students to enhance their general skills, including verbal communication, collaborative work, data finding, and analytical and evaluative abilities, in an ongoing manner [6]. These videos are also incorporated into our course's welcome instructional video.

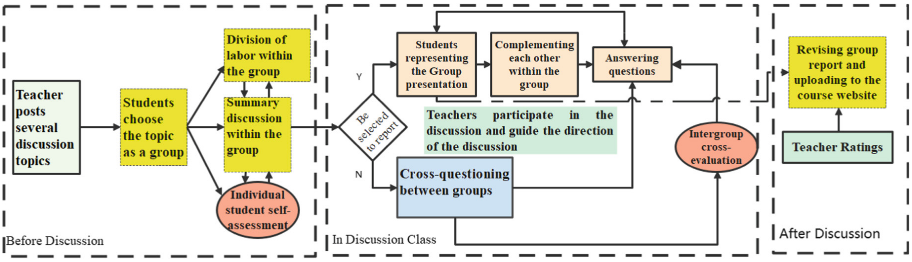

Fig. 10. The Implementation Process of the Discussion Classes

Application Effectiveness. Both the end-of-class student feedback questionnaires and the feedback questionnaires for students' four years of study before they graduate from college have indicated that the progressive experiment system in this course is considered to be both challenging and interesting to learn and join. In addition, the high-quality group discussion sessions are a key feature of this course. Through well-designed discussion topics and active guidance and facilitation by the instructor, we observed a significant increase in the number of students participating in the discussions from the beginning to the end of the semester, with students' roles in the discussions evolving from singular to diverse. Students reported a significant improvement in their individual willingness to collaborate and in their oral presentation skills. This further promoted students' independent learning and achieved the goal of organizing teaching and learning centered on students' development.

5 Value of TLMs

After the last five years of construction, the TLMs of our course have been built up in a relatively stable way according to the three levels of "learning, practicing, and creating", which have been continuously enriched and revised in the teaching process every year. Students have given very positive feedback. We post questionnaire in the middle and end of each term. And we also post questionnaire to senior students before they graduate. The level of satisfaction among students towards our course is high (see Fig. 11). And the TMLs are well-received each year.

Compared with the single form of teaching resource construction based on knowledge points, the construction of hierarchical TLMs based on Bloom's taxonomy makes up for the shortcoming of Bloom's model which only has goals but lacks paths and methods to achieve them. And according to the position of the course in the whole professional teaching system and its characteristics, the rich TLMs we construct are suitable for the multidimensional goals of the curriculum. For teachers, they can get direct feedback on students' learning effectiveness, and students' learning and practice

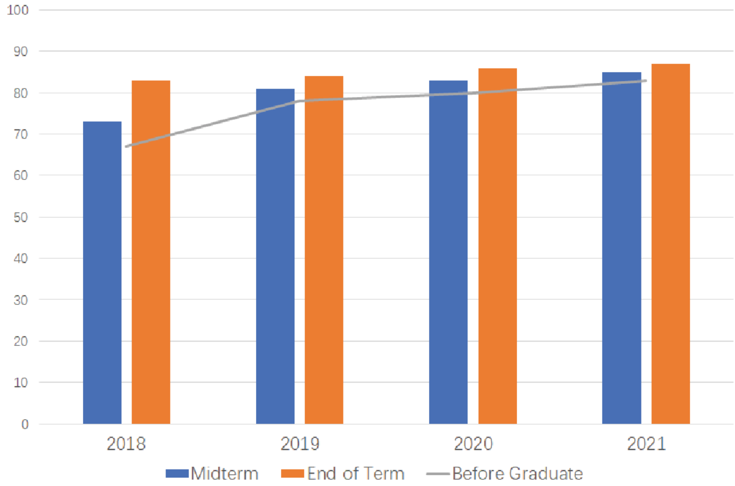

Fig. 11. Students Satisfaction with Computer System Course

data can be provided to instructors based on the learning process formed by the various platforms. Students can constantly discover their learning shortcomings in the learning and practice process based on these TLMs, which can provide true and timely feedback on their learning progress. It promotes the continuous development of students' learning abilities.

For the curriculum, the TLMs can also provide effective supporting evidence for the course construction to explore whether the relevant objectives are achieved and what should be revised or supplied for our students. Thus, the constructing direction of the curricula can be expected.

In addition, these TLMs, most of which are informational and digital in construction, are very suitable for offline learning, online learning, or hybrid teaching while the epidemic is still in progress.

6 Conclusion

The TLMs constructed based on Bloom's taxonomy are valuable. It is not only guaranteed to implement students' development-centered teaching objectives but also cultivated students' abilities, especially higher-order abilities. Then students' learning data can be obtained in real-time. The TLMs are very worthy of construction— Students can clearly identify their learning shortcomings and dynamically adjust their learning methods and efforts. Teachers can grasp students' real learning effectiveness in a clearer and more timely manner, which promotes instructors to make adaptive revisions of teaching focus and methods to achieve student-centered teaching.

The construction of teaching and learning materials in this way is also suitable for similar professional curricula, and the construction of course resources based on Bloom's model is also applicable to any courses with hierarchical teaching and learning objectives.

We will continue to enrich our teaching and learning resources based on the existing framework for building TLMs. In addition, we will strive to identify learners with different learning characteristics and adopt targeted and effective teaching tools to motivate learners, in order to helping students achieve better learning outcomes and enhancing their meta-cognitive abilities. This will be a major focus of our future research.

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Design Scheme of Network Security Experiment Based on Packet Tracer

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Abstract. This study analyzed the training needs of network security talents. According to the current teaching environment of online teaching and the characteristics of network security experiment, this paper put forward the design scheme of virtual simulation experiment based on Packet Tracer, which has been applied to the course of "network security technology experiment" and achieved good results.

Keywords: Network Security · Packet Tracer · Virtual Simulation Experiment

1 Introduction

With the rapid development of information technology, the problem of network security has become increasingly prominent. Cyberspace Security has become an important part of national security. Seizing cybersecurity control is the strategic commanding heights of all countries [1]. The cultivation of network security talents is the foundation and prerequisite for national network security. Therefore, many courses on network security have been offered in Colleges and universities.

Experimental teaching is a key link in the cultivation of network security talents, because experiments can be used to carry out practical exercises of network attack and network defense. However, when colleges and universities conduct experimental teaching, there are often problems such as outdated network equipment and low configuration, and the network environment cannot meet the needs of attack and defense drills [2]. At the same time, in the COVID-19 epidemic environment, online and offline hybrid teaching methods are widely adopted, and the experimental environment for network attack and defense is limited.

In this paper, Packet Tracer, Cisco's virtual simulation experiment software, is introduced into the course of "network security technology experiment", and the experimental teaching scheme is designed.

2 Packet Tracer

2.1 Functions of Packet Tracer

Cisco Packet Tracer [3] is a cross-platform network simulator software from Cisco, which can create topologies of different network connection types and network scales, support a series of network protocols, and simulate various network devices [4].

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As an auxiliary teaching tool and virtual simulation experiment platform, Packet Tracer can complete the following functions in experimental teaching:

- Complete the design, configuration and debugging process of the network.
- Solve security issues in complex network environment
- Simulate the operation process of the protocol

2.2 Operating Mode of Packet Tracer

Packet Tracer includes real-time operation mode and analog operation mode [5].

- The real-time operation mode can simulate the actual operation process of the network, and automatically complete the execution process of relevant protocols after completing the configuration of network equipment.
- In the simulated operation mode, users can observe and analyze every step in the process of network end-to-end transmission.

3 Experiment Teaching of Network Security

The experimental teaching of network security is an auxiliary and supplement to the theoretical teaching, which can help students deepen their understanding and mastery of theoretical knowledge. At the same time, experimental teaching can help students expand and comprehensively apply the theoretical knowledge of network security [6].

"Experiment of Network Security Technology" is a general elective course offered by Nankai University. The course combines theory with experiment to cultivate students' network security knowledge and skills, so that students can become potential power of network security talents.

3.1 Teaching Objectives

The teaching objectives of this course include:

1) Knowledge objective
   Understand the importance of network security and the basic requirements of network security; Understand the working principle of network protocol and the common theories of network attack technology and network defense technology.
2) Ability objective
   Students can perform basic configuration of network security; can use the network simulation experiment platform Packet Tracer to conduct common network attack and defense experiments, and have certain network defense skills.
3) Literacy objective
   Enhance students' awareness of network security, make students pay attention to the security protection of computers and networks, understand the importance of network security, and realize the sense of urgency that "without network security, there will be no national security".

3.2 Teaching Content

This course combines theory with experiments, including network security theory and experiments of network attack and defense. The specific teaching content is shown in Fig. 1.

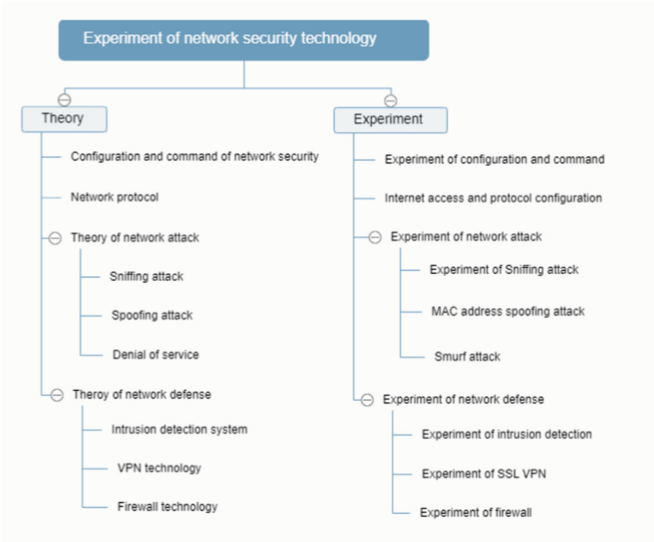

Fig. 1. Teaching content

Firstly, the basic configuration and commands of network security are introduced, and the corresponding computer configuration and network monitoring command experiments are carried out. Then, introduce the TCP/IP network protocol, and carry out the experiment of internet access and network protocol configuration. Next, from the two aspects of network attack and network defense, theoretical learning and corresponding experimental operations are carried out respectively. Network attacks include sniffing attacks, spoofing attacks and denial-of-service attacks; network defenses include intrusion detection systems, VPN technology and firewall technology.

4 Experiment Design Based on Packet Tracer

Due to the limitations of network equipment and environment and the background of COVID-19, it is obviously unrealistic to conduct experiments in a real network environment. Cisco packet tracker is a virtual lab platform for network design, simulation and modeling. Users can model complex systems through Packet Tracker without special network communication equipment, which greatly saves the cost [7]. Therefore, the experimental platform of this course adopts Packet Tracer, and the experimental scheme is designed and implemented based on Packet Tracer.

4.1 Design Scheme of Experimental

The experiments are closely integrated with network security theory, and are carried out from several aspects such as computer security configuration and commands, network protocols, network attacks and network defense. All experiments can be performed under Packet Tracer. In particular, the network attack and defense experiment can realize the real operation experience in a virtual environment. The detailed experimental design of network attack and network defense is shown in Table 1.

Table 1. Design of Experiment

Name of Experiment	Content of Experiment	Purpose of Experiment (Theoretical Verification)
Sniffing attack	Implement sniffing attack process with hub	The process of sniffing attacks using hubs Sniffing attack will not affect the normal MAC frame transmission process
Spoofing attack	MAC address spoofing attack experiment	MAC table establishment process of switch Mechanism of MAC frame forwarding by switch Principle of MAC address spoofing attack
Denial of service	Smurf attack experiment	ICMP echo request and response process Smurf attack process
Intrusion detection	Experiment of intrusion detection	Intrusion detection system configuration process Working mechanism of intrusion detection system based on feature base Feature definition process
VPN	Experiment of SSL VPN	How SSL VPN gateway works Configuration and working process of SSL VPN gateway
Firewall	Extended packet filter experiment	Firewall configuration process The process of limiting the transfer function between interfaces

Take Smurf attack as an example to illustrate the functions of Packet Tracer.

The attacker broadcasts an ICMP echo request message in the network. The source IP address of the message is the IP address of the attack target, and the destination address is the broadcast address of all 1s. That is to say, all terminals in the network receive the message and then respond to the message, that is, they send ICMP echo response message to the source IP address (attack target). This leads to network congestion and the target host cannot communicate normally.

1) Simulate the topology of the network
First, place the network device in Packet Tracer and connect them. As shown in Fig. 2.

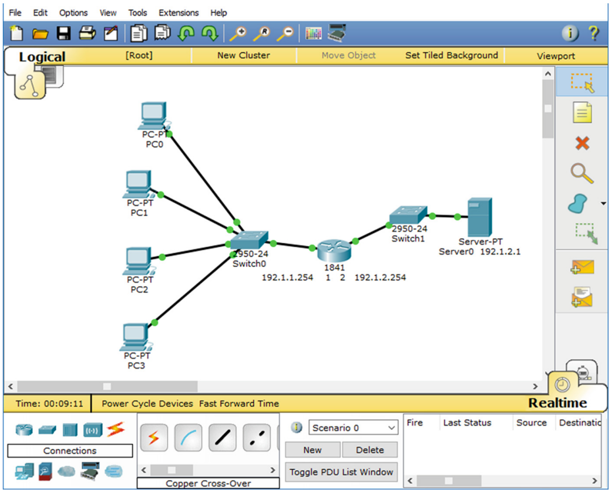

Fig. 2. Topology of the network

2) Configure the network
Use the graphic interface configuration mode of Packet Tracer to configure the router interface, as shown in Fig. 3.

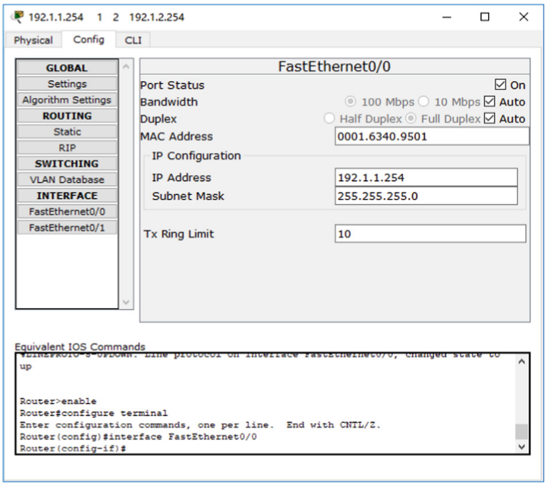

Fig. 3. Topology of the network Interface configuration

Use the command line interface configuration mode of Packet Tracer to configure the DHCP server, as shown in Fig. 4.

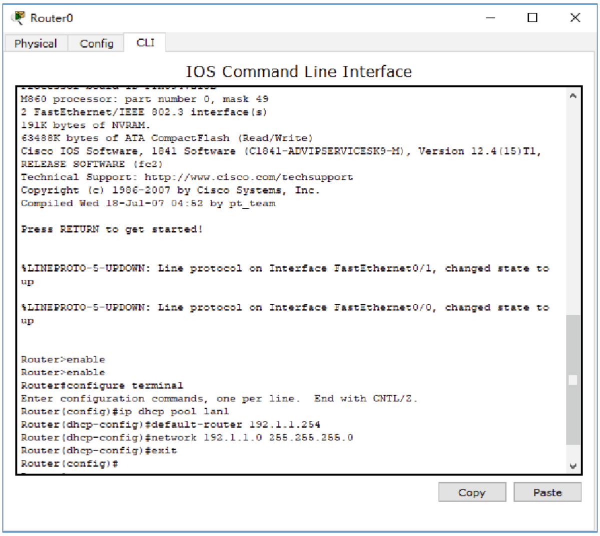

Fig. 4. DHCP configuration

3) Analog data message transmission
Switch to the simulation operation mode and generate ICMP echo request message. The message transmission process of Smurf attack can be observed in Packet Tracer. As shown in Fig. 5.

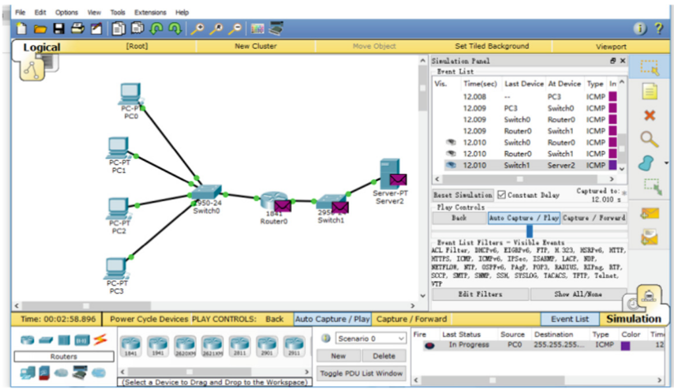

Fig. 5. Message transmission process

4.2 Implementation Effect

Ket Tracer, the experimental teaching has been significantly optimized and the teaching quality has been significantly improved, which is mainly reflected in the following aspects.

1) Learning interest has increased significantly
   Due to the limitation of hardware equipment, many courses in network security are mainly theoretical, and even the construction of network structure and the configuration of network protocol cannot be fully operated. Teaching divorced from practice makes students lose interest and confidence.

   After using Packet Tracer, each student can conduct experiments independently and make full use of the learning time in the classroom. The data transmission process in the form of animation allows students to understand knowledge more intuitively. Students' learning interest, enthusiasm and participation have been significantly improved.
2) The ability of students has been improved
   In practice teaching, using Packet Tracer for simulation experiment can well improve students' knowledge mastery level and autonomous learning ability.

   Through the virtual simulation experiment, students have a more solid understanding and mastery of network security theory. Students not only master the principles of sniffing, spoofing attack and denial of service attack, but also conduct attack and defense experiments, which greatly improves students' problem analysis ability, practical ability and comprehensive innovation ability.
3) Safety awareness has been improved
   Students feel the importance of network security, improve their security awareness, and have some methods and skills to prevent network attacks.
4) Students' high evaluation
   Students' evaluation of the course is very high, and the students' evaluation score on the teaching system is as high as 99.118 points.

In addition, students' evaluation of the course was investigated through questionnaires.

Questionnaire topic: The experiment of Packet Tracer virtual simulation software can realize network attack and defense drill, and improve my knowledge application ability and practical ability.

The results of the questionnaire are shown in Fig. 6. Among them, 58.06% of the students strongly agree, 25.81% of the students agree, 12.9% of the students are uncertain, disagree and completely disagree are 0% and 3.23% respectively.

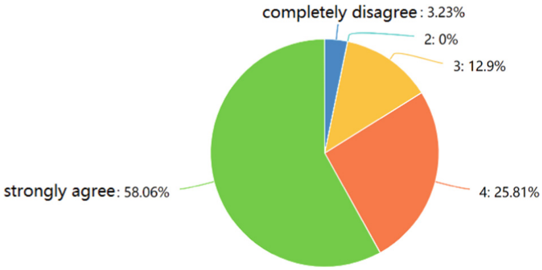

Fig. 6. Evaluation of capability improvement

Questionnaire topic: Do you think the course meets the expectations and whether you are satisfied.

The results of the questionnaire are shown in Fig. 7. Among them, 48.39% of the students are very satisfied, 32.26% of the students are satisfied, 16.13% of the students are uncertain, 0% are dissatisfied and 3.23% are very dissatisfied respectively.

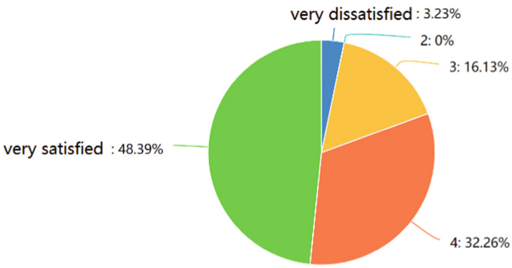

Fig. 7. Evaluation of satisfaction

5 Conclusion

In this paper, we introduced the design scheme of network security experiment teaching based on Packet Tracer. Firstly, we introduced the teaching objectives and contents of " Experiment of Network Security Technology". Then, the experimental teaching scheme based on Packet Tracer was introduced, and taking Smurf attack experiment as an example, the functions of Packet Tracer in the experiment were introduced. Finally, we analyzed the implementation effect from the aspects of students' interest, ability improvement, safety awareness and students' evaluation. It is hoped that this scheme can provide reference for other network security experimental teaching in colleges and universities.

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The Research on Culture Protection by Information Technology in Translation

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Abstract. The speeding of globalization strengthens the communication among countries, which makes cross-culture communication become a hot topic these days and translation becomes a vital means to achieve the communication. However, globalization also leads some cultures to gradual extinction through culture assimilation, culture neglecting or other courses. Nowadays, more and more countries realize the importance and the urgency of protecting their national cultures. As the development of information technology (IT), this paper tries to find out how IT protects national cultures in translation by taking cultural translation as examples. By studying the advantages and disadvantages of IT applying to translation, under the Prototype-model translation theory, the paper proposes that IT can help translators and readers to understand the literary works and their culture background more efficiently and conveniently, which facilitates the cross-culture communication, protects and spreads the national cultures to push forward the world culture development.

Keywords: information technology · culture protection · translation

1 Introduction

With the development of the globalization and the cross-culture communication, some national cultures are facing the issue of culture extinction, as some of them are assimilated by other cultures or some of them are neglected by their natives. More and more countries realize the importance of their national cultures and pay more attention on finding ways to protect and export cultures. Except using Geo-Information Model, Big Data, Cloud Computing, Virtual Reality and other kinds of information technology (IT) to record the history and national cultures, taking the importance of translation in cross-culture communication into consideration, applying IT to translation is also one of the most vital means.

In recent years, many research scholars have studied the relationship between IT and translation. Professor Chen and Professor Mo came up with the idea that the development of translation is linked to the development of IT, but IT is not the only reason that push translation forward [1]. Professor Kang thought IT can help people to translate more

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efficiently, but it should not be overused and the translators should improve their own capacity [2]. Another researcher professor Sun also agreed with this ides and pointed out that IT can help translators or readers to search for the information or the culture background of the articles or literature works and improve the accuracy and professionalism of the translation [3]. Besides, many research scholars have also studied the application of IT in culture protection. Professor Dang and other scholars from Tsinghua University analyzed that in recent years, China has used IOT, Big Data, Cloud Computing and many other kinds of information technology to record and protect historic buildings and national cultures in a digital way [4]. Not to mention the relationship between translation and culture protection. Scholar Abbasi and other researchers thought that because of the variety of language with different culture and the the necessity of communication in normal life, translation becomes the efficient way to realize culture and knowledge communication [5].

However, most of those scholars only discussed one of those three relationships mentioned above, few of them talked about the relation between IT, translation and culture protection. In this paper, this relationship will be talked about. Under the Prototype-model translation theory proposed by Zhang Jin, Zhao Lianbin and many translation scholars, his paper proposes that IT serves the translation to make translation become more accurate, help translation involve and express more cultures [10]. Therefore, on the one hand, the national cultures will be protected and inherited and will be exported to other countries; On the other hand, the original culture can also learn excellent cultures from other countries, which is also a kind of culture protection for other countries. In some extent, all the cultures in the world will be advanced together.

2 Translation and Culture Protection

2.1 The Relationship

Translation is a way to protect national cultures. On the other side, national cultures facilitate the birth of translation, which means culture protection can improve the translation activities. Different language derives from different culture and the culture is reflected and passed on by language [5]. As human living in a large society where communication is inevitable, translation becomes a bridge of different language and its culture, so translation is also a way to protect the culture. In western world, many scholars believe that western culture derived from ancient Greek civilization which formed by the culture of ancient Egypt and the Near East. The Greeks learned mathematics from the ancient Babylonians, learned theology from the Jews and learned architecture from Arabians. At that time, the pictograph and the cuneiform were created. Their cultures were formed, too. All these learning activities were based on the communication between these cultures by translation [6](p4). Their cultures were protected by inheriting and developing in language through translation, and became the vitality of translation.

2.2 The Method

Analyzing from the examples mentioned above, the way to protect national cultures in translation is that the translators translate not only the language, but also the culture background, history, conventions and so on, in order that the culture can be understood by the people in other countries and can be inherited and developed through culture communication. Even if this culture is extinct because of some unpredictable accidents in the future, we can still trace it back in the translated copies.

3 Translation and IT

IT stands for information technology which includes internet technology, multimedia technology, computer technology, IOT, cloud computing and so on. This paper mainly talks about translation machine and information retrieval (IR) included in internet technology.

3.1 The Relationship

Except for the relationship between translation and culture protection, the relationship between translation and IT emerged with the technical progress. On the one hand, as the rapid development of technology, the translation field is inevitably influenced by it. On the other hand, translation also contributes to the development of IT.

In 1930s, French scientist G.B.Artsuoni gained the patent of mechanical multilingual dictionary, which symbolizes the beginning of electronic translation era [2]. Translators are benefited from IT in three aspects. First of all, IT helps translators get the exact meaning of the words, professional words in particular. Professor Ye said in his article that IT is clever enough to translate some "hard texts" like the texts in field politics, economy and law, especially formal texts, which can avoid the distortion of the text caused by the translator's over-translation [7]. With large corpora, IT leads the translation activities to a more efficient and convenient way. People can quickly get the accurate translated words and sentences by only copying the source language into the apps. Some extremely professional words can also be found, like, "Frequency-Division Multiplexing (FDM)", "Spread-Spectrum Technique", "Compact Disc Read-Only Memory (CD-ROM)" and so on. Translators can simply use the apps to find the corresponding word in different languages, if they don't know the meaning of the word or they suddenly forget it.

Secondly, IT helps reduce the work pressure of translators. Under the circumstances of globalization, the communication among countries becomes more and more regular. The demand of translation grows rapidly, which increases the work pressure of translators. Thanks for the help of IT and translation machine, translators avoid suffering from analyzing the complex sentence structure or reading a mass of files. The translation machine or the electronic translation system will use their large corpora to translate the files into the first version, so the translators only need to check and polish it.

Thirdly, IT helps translators to search for the culture background or the history more conveniently in a short time. Take some literature works as an example. One same literary images will express different emotions in different poems, like "the west wind". In the poem *Ode to the West Wind*, it was written: "O wild west wind, thou breath of Autumn's being, Thou, form whose unseen presence the leaves dead… [8]" Shelly shows the power of the west wind and expresses his compliment to the west wind with the hope for the success of the revolution. However, in China, "west wind" express a feeling of sadness and loneliness. In the Chinese poem *Tune: Sunny Sand Autumn Thoughts* written by Zhiyuan Ma, "west wind" is used in the line "On ancient road in the west wind a lean horse goes… [9]" In this poem, the west wind expresses the bleakness of Autumn. Therefore, before the translators translate the literature works, they should comprehensively learn the culture background and what the author wants to express. With the assistance of IT, this kind of knowledge can be quickly searched on the internet so that the translator can do the translation work more precisely and correctly.

On the other side, translation contributes to the improvement of IT. After translating some advanced researches or studies of IT, the advanced technology can be introduced in different countries to facilitate the growth of IT in the whole world.

3.2 The Application of IT

In translation, the application of IT can be mainly divided into two aspects: translation machine and IR. The translation machine with the latest and large corpora assists the translators in efficiently finishing massive translation works or finding appropriate words. The IR function assists the translator in doing the research in culture background, history background or the creation background of a literature composition so that the main idea of the composition can be correctly translated into different languages and be basically understood by the people in different countries.

4 Role of IT in Culture Protection

4.1 Prototype-Model Translation Theory

The Prototype-model Translation Theory is a practical theory in translation. Professor Zhang Jin mentioned it in his book *Principles of Literary Translation* in 2005. In 2012, professor Zhao Lianbin summarized this theory in his journal Research Focus and Theoretical Perspective of Prototype-Model Translation Theory. Introduced by those two professors, this theory takes the original text as the prototype and the translated text as the model [10]. Model is based on the prototype, so the translation has to be based on and be faithful to the original text not only in terms of content and context, but also in terms of linguistic form. Besides, the essence of this theory is reader-centered theory, which means the purpose of translation is to meet the needs of readers [11].

According to this theory, author did some researches facing to the public and established some tables which compares some versions translated by translators and translation machines to analyse the advantages and disadvantages of IT. The result can be seen as follows (Table 2):

The author collected a total of 70 valid questionnaires. Nearly half of the respondents disagree with the opinion that translators can be replaced by the machines and about 30% of the people are neutral. Therefore, there are still many people believe that translators are better than the machines. Besides, Considering the reader-centered theory, author divided the respondents into two groups: translation-related group and non-translation-related group, because in the prototype-model translation theory the readers can be divided into professional readers and non-professional readers, which is the reason why translators

Table 1. Different versions translated by different translation machines and translators

Translation Translation machines **Original Text**	**"Intend a zealous pilgrimage to thee..."**	**"speak of the devil"**
Youdao Translation	"打算向你狂热地朝圣"	"说曹操，曹操到"
Baidu Translation	"意愿一次热情的朝圣"	"说曹操，曹操到"
Google Translation	"打算向你热心朝圣"	"说起魔鬼"
Chen Caiyu	"我的思想向热忱的朝圣者，到你身边"	——
Xu Yuanchong	——	——
Arthur Waley	——	——
Collins Dictionary	——	"说曹操，曹操到"

Translation **Original Text**	**"Trying to please an audience is the kiss of death for an artist."**	**"结庐在人境，而无车马喧"**
Youdao Translation	"试图取悦观众是艺术家的死亡之吻"	"Knot in the border, and no horses cry"
Baidu Translation	"试图取悦观众对一个艺术家来说是一种死亡之吻"	"Jielu is surrounded by people, but there is no noise of cars and horses"
Google Translation	"试图取悦观众是艺术家的死亡之吻"	"The hut is in a human environment, without the noise of carriages and horses"
Chen Caiyu	——	——
Xu Yuanchong	——	"Among the haunts of men I build my cot, There's noise of wheels and hoofs, but I hear not"
Arthur Waley	——	"I built my hut in a zone of human habitation, Yet near me there sounds no noises of horse or coach."
Collins Dictionary	"试图取悦观众对艺术家来说无疑是自取灭亡"	——

Table 2. Views on whether machine can replace translators

Views	Extremely Agree (81-100 points)	Agree (61-80 points)	Neutral (41-60points)	Disagree (21-40points)	Extremely Disagree (0-20points)
respondents	1.4%	20%	24.3%	32.9%	11.4%

(Note:Accurate to one decimal place)

Table 3. The most acceptable translation of literature chosen by different readers

Readers' major or job / Versions	The Translation of "Intend a zealous pilgrimage to thee..."			
	Translated by Youdao Translation	Translated by Baidu Translation	Translated by Google Translation	Translated by Chen Caiyu
Translation related	19.2%	11.5%	3.9%	65.4%
Others	13.9%	13.9%	2.3%	69.8%

major or job / Versions	The Translation of "结庐在人境，而无车马喧"				
	Transla-ted by Youdao Translation	Transla-ted by Baidu Translation	Transla-ted by Google Translation	Transla-ted by Xu Yuan chong	Transla-ted by Arthur Waley
Translati-on related	11.54%	0	0	65.4%	23.1%
Others	16.2%	2.3%	9.3%	48.8%	23.3%

(Note:Accurate to one decimal place)

have to meet the readers' need when they are translating the original texts [11]. In this research, there are 38% translation-related respondents and 62% non-translation-related respondents. In both of the translation of two poems, the majority of the respondents from two groups like the versions translated by translators which also shows that translators can better meet the need of the readers.

However, among the versions translated by machines, there are some different choices. Youdao translation is more acceptable in the translation-related group and Baidu translation is more acceptable in the non-translation-related group. Comparing these two translations, it can be found that Baidu translation is more like the literal translation and Youdao translation is more likely to express the meaning of the poem. Therefore, the professional readers are more likely to study the meaning of texts, while others are more likely to understand the literal meaning of them. This is also one of the opinions mentioned in the prototype-model translation theory [11].

All in all, every coin has two sides. Translators are more acceptable than machines and can not be replaced by the machines. However, different readers have different need, which requires the translators to consider the need of readers while translating the original texts with the help of IT. IT has both advantage and disadvantages in terms of culture protection in translation, which can be analyzed as follows.

4.2 The Advantage of IT

From the ideas and statistics listed above, IT makes great contribution to translation activities which makes great contribution to culture protection. Therefore, obviously, IT plays an important role in protecting national cultures in translation area.

On the one hand, when translator use translation machine doing the translation work, the translation machine will provide basic translated version including complete structure and main idea of the text for the translators, which also maintain the simple culture symbols in the translated version. In the 26^{th} and 27^{th} poems of Shakespeare's Sonnet, the words, "Lord" and "pilgrimage [12]" will be translated into literal meaning by translation machine (take Youdao Translator as an example), which are the words "Shen" and "Chao sheng" in Chinese. These obvious translated culture images show the Christian religion expressed between the lines, which also present the religious belief of the people in western countries and the effect of Christian religion on the western culture. With the assistance of translation machine, some typical culture images can be translated into exact corresponding words in different languages, retaining the national culture at the same time. Through these words, part of the national culture of source language will be easily understood and accepted by more people in different countries, which, to a certain extent, is a way to protect the national culture by spreading the culture to other countries.

On the other hand, IR function integrates culture background into translation better. Scholar Permatasari and Basari believe that the translation product loaded with culture aspects is experiences of the author about life with a particular cultural background [13]. Hence, before translating the source text, translators need to search for some information related to the text, like, the culture background of the source-language speaking countries and the target-language speaking countries. Then, Translators will add their understanding and cognition of culture background or creation background into the target text to make their translation be more close to the culture of target-language speaking countries, while retaining the culture of source-language speaking countries. Through reading those translated texts, the culture of the source-language speaking countries can be understood and learned by more people in different countries, which is also a kind of culture communication, protection and development. Take an Chines poem, *While Drinking* [15] as an example. A part of the poem is as follows, "Among the haunts of men I build my cot, There's noise of wheels and hoofs, but I hear not… [14]" In the first line of the poem, there is a Chinese word "Lu". After searching for the living condition of the poet on the internet, translators can easily find that at that time, the poet lived in a simple and crude house in the city. Professor Xu translated it into the word "cot". According to *Oxford Dictionary*, without being related to any kind of houses, it means a small bed with high dies for a baby. However, Professor Xu skillfully translated it with his own understanding of the culture. After searching for this word by using IR, translators can find out that in ancient English, "cot" means the cottage or the a small house. It is appropriate to translate the Chinese word "Lu" into "cot". Besides, "cot" gets the same end rhyme of "not" used in the next line of the poem [15]. In this translation, with the help of IT, it not only remains the basic meaning of "Lu" in Chinese, but also conforms to prosodic rules of English poems, which protects the Chinese culture, while adding the Western culture to realize the culture communication and development. According to Table 3, this is the most acceptable translation, which means it obeys the reader-centered theory.

4.3 The Deficiencies of IT

Although IT benefits translation a lot in protecting culture, there are also some deficiencies of it. First, translation machine can efficiently translate a mass of texts, except cultural texts. This idea is pointed out by Professor Cronin in her book *Translation in the Digital Age*, too. She believes: "Science and technology mainly serve scientific languages… Using online translation systems to deal with cultural languages (such as poetry) can only lead to troubles and obstacles [16]" She also suggests that "based on the characteristics of the fine thinking mode of translation, the choice of aesthetic, cultural and political meanings at any micro level (details) in the translation process cannot be separated from the translator who is full of initiative and spirituality [16]" Some inner cultural meanings behind the idioms or culture images and some important milestones in the history can't be translated exactly by the translation system. The English phrase, "kiss of death" means something causing the failure is seemingly helpful. When the translator copy this phrase onto the translation machine, can only be given the literal meaning (Table 1). Actually, if the translator search for the history of this phrase on the internet, he can find out that "Judas kiss" is the synonym of this phrase. These two phrases are derived from the *Bible*. Judas who betrayed Jesus was one of students of Jesus. Judas told the killers that the one who he kissed was Jesus. Then he kissed Jesus and Jesus was persecuted. After understanding the meaning of the phrase, the translator can find out some corresponding Chinese idioms, like "drinking the poison to kill one's thirst" or "sugar-coated bullets". It proves that in the digital age, the translators still play an important and dominant role in protecting culture by translating the cultural texts.

Besides, the machine-translated version need to be polished by translators to increase the charm of the original texts. Put the first two lines of the poem While Drinking mentioned above into Google Translate, the translated version is as follows, "The hut is in a human environment, without the noise of carriages and horses [15]" Compared with the version translated by professor Xu, it is obvious that human translation is better. In human translation, "Among the haunts of men I build my cot, There's noise of wheels and hoofs, but I hear not (Table 1)", translator changes the sentence structure and polishes it with end rhyme, which is more understandable and catchy by people in target-language speaking countries. Therefore, human translation protect both the Chinese culture and English culture by inheriting them among lines. This proves that IT still has some deficiencies in protecting national cultures in translation areas, it can only be the assistant of translators.

5 Conclusion

This paper proposed an idea that IT makes contribution to protect national culture by assisting translators in translating texts especially cultural texts. By listing some translation examples and doing some researches based on the Prototype-model Translation Theory, it proves that IT can and can only be the assistant of translators in protecting national cultures, because only human translation interprets the culture of both sides of languages in the translation projects. With the help of IT, translators will not only decrease their working pressure of translating a mass of files and texts, but also get more information about the culture background of each language, the history of each country, the creation background of each composition and so on, before starting their translation projects. Therefore, they have more time to polish the machine-translated version for remaining the source-language culture and adding target-language culture in the final version to meet different readers' need. It is a way to protect the national culture by inheriting and developing it in translation, spreading to other countries, achieving cross-culture communication and finally enriching culture diversity in the world.

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Teaching Reform and Practice for the Course of Web Application Development Technology Under the Background of Online Education

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Abstract. With the advent of knowledge economy, online education relies on the Internet and mobile terminals, it breaks the limitation of time and space of traditional education. Online education has gradually becoming a new way for people to learn. Under the special background of COVID-19 since 2020, online education has been well applied. The course of Web Application Development Technology is not only a course which is the core course in software development for computer majors, but also is a course with strong practicality and application. This paper analyzes the problems existing in the online teaching of the courses of web course under the background of online education, and presents a new scheme of the teaching reform measures for the course according to the characteristics of online education and the course of Web Application Development Technology which is well applied by the author's own practices.

Keywords: Online education · Core course · Course teaching · Reform measures

1 Introduction

Online education is an educational method based on Internet technology which has been increasingly used in people' life and study. As a new way to study and obtain learning resources, online education has gradually becoming an important new way of learning which prospect is broad by this way. Relying on the Internet and mobile terminals, online education breaks the limitation of time and space of traditional education. it has gradually becoming a new way for people to learn as the advent of the era of knowledge economy. With the spread of the COVID-19 since 2020, online education has been applied and practiced well which was very difficult to do in the past for learning. As an important course of software development ability for students whose major is computer science or software engineering, the course of Web Application Development Technology requires

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high practical ability of the students who wants to learn this course well in theirs learning [1]. To improve students' practical ability is an important requirement of engineering education in the world. Under the background of online education, how to break through the technical bottleneck and management barriers, how to improve the ability and quality of practical teaching, is the focus of current teaching research in the world [2]. Based on our teaching practice, this paper discusses how to carry out the teaching reform of Web Application Development Technology under the background of online education.

2 Problems Existing in Online Education at Present

After careful analysis and conclusion, we agreed that in the development courses of local colleges, to effectively solve the problems in online course teaching, the following four aspects need to be solved:

(1) How to solve the problems of poor network conditions and poor real-time teaching effect. As the medium of online education, the network status of teachers and students directly determines the effect of online education. With the development of national information technology, the basic network of our country has made a great progress. However, there are still some remote areas where the network is not very good, and there is even no network coverage. Due to the different regions where students' families are located, a small number of students' families are often in a state of no network or poor network signal [3]. Even when the network is in good condition, a large number of users using the network at the same time, which is also a challenge to the bandwidth of the network. In addition, Coupled with the limitation of real-time connections of various online education platforms, it is also a challenge for students to learn online.

(2) How to solve the problems of lack of self-control in the process of learning. Online learning is carried out through virtual classrooms by using mobile phones and the Internet as the tools which have too many temptations. Many students lack self-control to resist the temptations of mobile phones and the Internet. Some of them go to class with a mobile phone in one hand and do other things in the other, and some of them even turn on the online learning video in one hand and to sleep or play games on the other hand. It greatly reduces the effect of students' online learning.

(3) How to solve the problems of poor teaching experience and limited teaching practice environment. Web Application Development Technology is a course with strong practicality and application, which tests students' practical ability [4]. This course requires students to do a lot of practical operations which needs some skills. If the practice of traditional classroom teaching is copied to the platform of online education, it is far from effective. Due to the lack of immersive environment, students have various problems in the process of practice. How to obtain, understand and solve the problems encountered in online education practice courses in time is a big problem in the current online education.

(4) How to improve the way of online teaching examination and evaluation. As a core course, it is very important for teachers to evaluate the course which students study well or not.For courses with strong practical requirements, how to evaluate students'

practical ability and how to assess the seriousness of students in the learning process of this course is a big problem. Although each online education platform has its own evaluation methods, the examination and evaluation methods of courses in practice need to be improved in combining with the characteristics of the practice course.

3 Teaching Reform Measures

In order to solve the problems existing in the online teaching process of the course of web application development technology, the authors have been makes a more in-depth research through teaching practice according to the characteristics of the course and the reality of the students. The authors agree that the teaching reform of the course should be carried out from the following four aspects:

(1) Make Plans, Integrate Platforms, Give Full Play to the Advantages of Online Education

In the teaching process, first of all, teachers should formulate the online course plan and release the learning content of this course in advance. It is beneficial for students to understand the learning content of this course and to study in advance. Students can choose the right time to study according to their own network equipment conditions. Then teachers should choose the appropriate online education platform for teaching. In the teaching of this course, QQ group, XueXiTong, Tencent Conference, MOOC platform and Encoder are selected as the online teaching platform of this course [5]. We carry out the teaching of the course by integrating the advantages of each platform. QQ group is used for the release of course messages and the transmission of documents, XueXiTong is used for students' course check-in and homework submission, MOOC platform is used for students' self-study video learning, Encoder is used for students to do practice exercises. Tencent Conference is used for online live broadcasting of the course, its playback function is used to watch again after classes for students who have problems in learning. Other students also can watch the content after classes if they think it is necessary. After doing that we formulate the online assessment scheme and evaluate the course performance. At last we summarize the online course of this courses. The overall process of the course is shown in Fig. 1 [6].

(2) Real-Time Attention, Strengthen Interaction, Improve the Efficiency of Students' Online Learning

During the teaching process of the course, we send the link of the Tencent Conference to the QQ group which students have been already in before each class, the students are required to login with their real names before each class. In the course of each classes, we pay attention to the number of students by adding random questions and arranging classroom exercises [7]. After class, we get to know the learning situation of students through the statistical function of Tencent Conference. Then we assign homework through XueXiTong. We find out the problems which should be dealed with quickly in the classroom in time through the students' classroom learning statistics and after-class homework. We analyze the reasons for the students with poor learning results and provide after-class tutoring. The online course learning process is shown in Fig. 2.

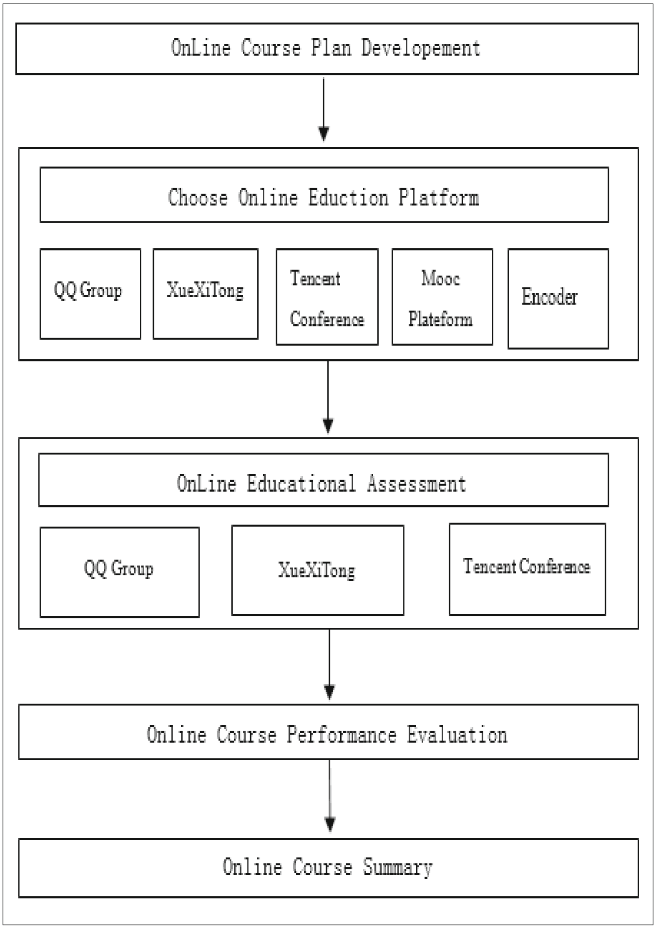

Fig. 1. Overall flow chart of online cources

The entire content of the course is shown in Table 1.

Table 1. Teaching contents of online courses

No	***Content***	***Knowledge point***	***Hour***
1	Basic of Web	a. Common Tags of HTML b. Basic knowledge of CSS c. Basic knowledge of JavaScript	2
2	Basic of Java Web	a. XML Syntax b. DTD Schema c. Installation and Startup of Tomcat d. Configuration of Eclipse	4
3	Basic of Servlet	a. Servlet Interface b. Servlet CycleLife c. Servlet Application	4
4	Request and Response	a. HttpServletRequest b. HttpServletResponse c. Chinese garbled code	4
5	Cookie and Session	a. Cookie Object b. Session Object c. Cookie and Session Application	2
6	JSP	a. JSP Characteristics and Principle b. JSP Basic Grammar c. JSP Implicit Object d. JSP Action Element	8
7	EL and JSTL	a. JavaBean Application b. EL c. JSTL d. EL Implicit Object	4
8	JDBC	a. JDBC b. JDBC API c. Operate Database	4
9	Upload and Download	A.Upload b. Download c. Commons-FileUpload	4
10	Comprehensive project (Design and Realization of Book Store)	a. Requirement Analysis b. Functional Structure Analysis c. E-R and Table Design d. Project environment construction e. Register and Login f. CRUD Development	12

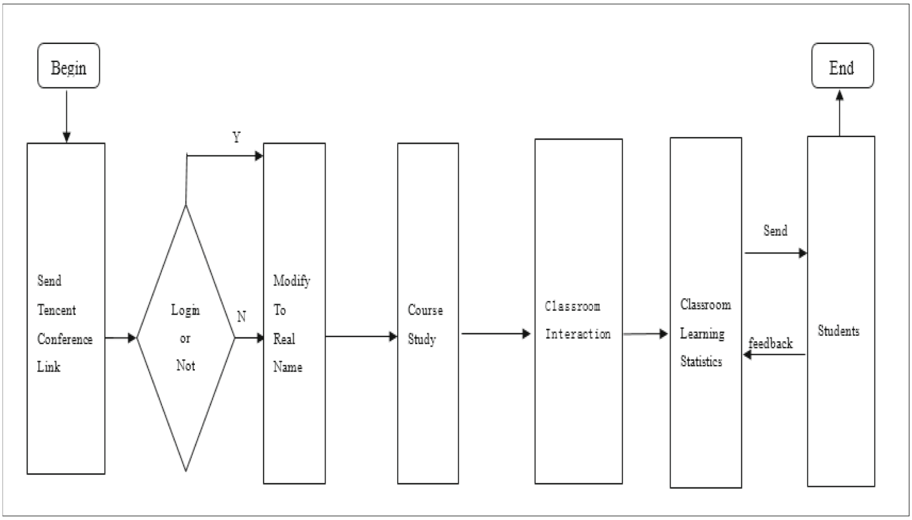

Fig. 2. Online course learning flow chart

(3) Driven by Practical Projects, Improve Students' Learning Enthusiasm

The course of Web Application Development Technology is a highly practical course, which requires students to have strong practical ability. In the teaching process of this course, we enhance students' interest and initiative in learning by combining with theoretical knowledge and practical skills. We also use ten small cases which help students to obtain practical skills to enhance students' enthusiasm in learning this course. These cases are carried out by using the Encoder platform which was well applied in a number of universities. The cases of this course are shown in Table 2 [8].

Table 2. Auxiliary cases of online courses

No	***Case name***
1	Design of Book Mall
2	Eclipse configuration Tomcat
3	Develop servlets using Eclipse
4	Chinese input and output case
5	User login case
6	Implementation case of registration module
7	Unified coding case of the whole station
8	CRUD case using JDBC

(*continued*)

Table 2. (*continued*)

No	***Case name***
9	Upload and Download case
10	Book Mall case

(4) Reform the Evaluation Method of Curriculum, Aim to truly Reflect Students' Learning Level

The effect of students' learning is directly reflected in their course scores. The students' grades in practical courses should not be simply composed of examination score and usual perform which were used widely in traditional courses examinations. The examination of practical courses should reflect the level of the students' practical ability [9]. Therefore, the way of performance assessment of the course is used in the form of project investigation and usual performance. The project investigation accounts for 60%, and the usual performance accounts for 40%. We document the final exam plan in QQ group one month ago before the end of the course. According to the characteristics of online teaching, we choose a specific time to inspect projects which were done by students through Tencent conference when the course is over. The online project inspection time is 8 min for each student, of which 5 min are for the student's project self-display, 3 min are for the teacher to ask questions which according to student's project self-display [10]. The students answer the question which teachers ask for. Finally, students are required to write a course report according to their own projects after the completion of the project. The students' project scores are evaluated according to the students' project situation, answer questions and course report. The proportions of the three parts are 40%, 40% and 20%. The usual scores mainly check the students' performance, it includes attendance, homework and class interaction, accounting for 40%, 40% and 20%. Through the composition of the above results, it not only ensures the effect of classes in students' normal class, but also ensures the improving of students' learning initiative. we achieve good results by using the methods of above ways. The composition of course scores is shown in Fig. 3.

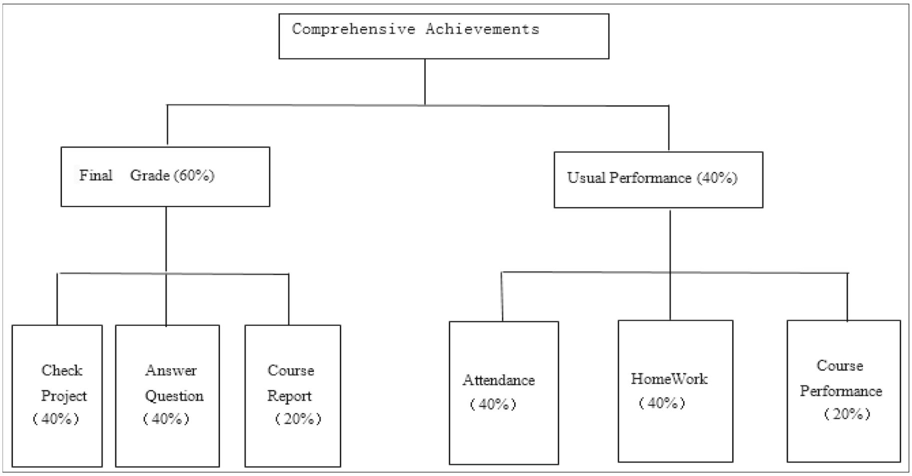

Fig. 3. Composition of online course scores

4 Conclusion

With the development of the times and the continuous integration of information technology into education and teaching, online education has becoming a very important means of current education. The course of Web Application Development Technology is a course which needs strong practical and comprehensive abilities. Under the background of online education, teachers' practical teaching ability and students' practical ability has been improved by selecting appropriate online education platforms which are well applied in student's learning. We have adopted the combination of live broadcast of courses and case teaching in the process of course teaching. We also have actively optimized the curriculum assessment mechanism and other teaching reform measures. Through the above measures, the teaching level of teachers has been greatly improved.

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Research on the Construction and Preliminary Application of Digital Teaching Resource Database

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Abstract. The school establishes a leading group through investigation and research, The division of labor is in place for work arrangement, the hardware is combined with the school network to build facilities for follow-up, the teachers establish and constantly update the information concept, and initially establish the school digital teaching resource library platform. In addition, the formulation, supervision and implementation of the resource library program, as well as training, have promoted the initial application of the school's digital teaching resource library.

Keywords: Digital Teaching Resource Library · Construction · Application · Deep Approach

1 Introduction

Today, with the rapid development of information technology, various high-tech technologies have penetrated into all walks of life, The door of education has also been knocked open, From paper books and textbooks to electronic lesson preparation, And then to network resource sharing, Information technology has been gradually accepted and applied by front-line teachers, but the application of information technology in teaching still stays at the level of projection and simple use of PPT. With the concept of integration of information technology and disciplines put forward, it is required that information technology should be applied to teaching, serve teaching, solve difficult problems in teaching, and become an important link in teaching [1].

2 Core Concepts

Teaching resource library is a collection of various digital resources related to education and teaching under a powerful management platform. The teaching resources defined in the Technical Specification for the Construction of Teaching Resources refer to the teaching information transmitted by digital signals on the Internet, which belongs to a

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subset of learning objects. The construction of teaching resources can have four levels of meanings. First, material teaching resources are mainly divided into: media materials, test questions, test papers, literature materials, courseware and network courseware, cases, frequently asked questions and resource catalogue index; The second is the construction of online courses; The third is the evaluation of resource construction; Fourth, the development of teaching resource management system; This study is to integrate the visual digital resource platform in the material teaching resources. Digital resource is one of the manifestation forms of literature information, which is the sum of information resources published, accessed and utilized in digital form by integrating computer technology, communication technology and multimedia technology, such as courseware, test paper, micro-course, courseware and so on.

Construction of digital teaching resource database: The construction of school-based resource library has always been an important part of school information construction. The goal is to build a school-based resource library with the characteristics of the school and meet the needs of teachers and students for educational resources, which is the core content of resource library construction. The construction of school-based resource library system is the foundation of building school-based resource library. Establishing a platform that is beneficial to teachers and students, and building a visual educational resource library that conforms to the development of school education and teaching are the basis for the effective, orderly and efficient operation of school-based resource library and an important cornerstone for the construction of resource library.

Application of digital teaching resource library: The application of school-based resource library lies in the establishment of educational and teaching resource library with school characteristics, which is suitable for the actual situation of schools, and can solve the problem of low utilization rate of educational equipment and the application bottleneck problem encountered in the development of IT application in education sector. The application of school-based resource library construction mainly lies not in the resource library itself, but in the influence and promotion of IT application in education sector brought by the construction process. The application of school-based digital resource library is not only a new understanding of the construction of IT application in education sector, but also a new idea of the construction of IT application in education sector [2].

3 Theoretical Basis

3.1 Documents from Ministry of Education of P.R.C.

Ministry of Education: The Curriculum Standards for Compulsory Education (2011 Edition) [3] proposes to strengthen the construction of curriculum resources. According to the actual situation of each region, we should make an overall plan for the development and utilization of curriculum resources, organically coordinate the beneficial curriculum resources in schools, society and network, create favorable conditions and environment for teachers to carry out teaching reform in depth, enrich teachers' teaching content and stimulate teachers' teaching vitality.

The Curriculum Standard for Information Technology Application Ability Training of Primary and Secondary School Teachers (Trial) [4] puts forward: to promote the mixed training of combining network training with teaching practice, and to promote the combination of teachers' learning and application. It also proposes to build a batch of high-quality training curriculum resources that can meet the local reality and meet the needs of front-line teachers' education and teaching, and focus on building network curriculum resources to meet the needs of teachers' individualized learning. It provides a theoretical basis for the construction of school-based digital resource library in our school.

3.2 Deep Approach

Tochon (2014:60) proposed a revolutionary education approach, which targets deep education [5]. Deep Approach advocates a deep integration of intradisciplinary, interdisciplinary and transdisciplinary knowledge [5, 6]. Therefore, Deep Approach has naturally become one of the theories supporting the construction of digital teaching resource library. We also believe that the application of digital teaching resource library will be helpful for students to realize their deep learning.

4 Main Line of Research

See Fig. 1.

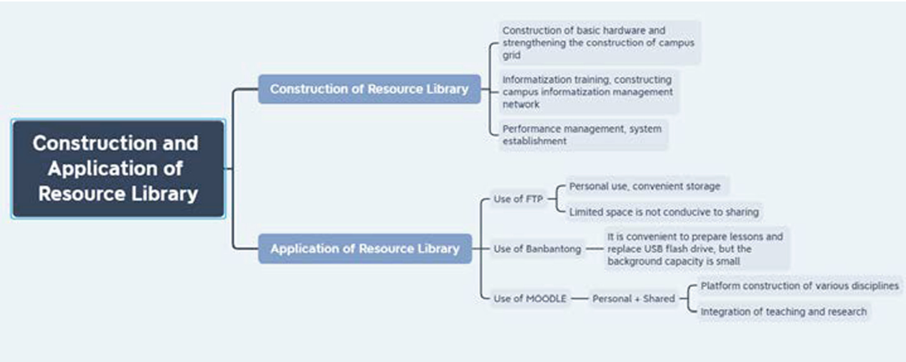

Fig. 1. Study main line diagram

5 Research Process

5.1 Research Methodology

Investigation and analysis method: We carry out comparative research on the construction and application of resource library, collect and sort out the educational and teaching theories and other materials related to the teaching of teaching resource library, and provide a framework and methodology for the research. We Investigate the hardware resources and software resources of the school, consult, collect and analyze the related data of the construction and application of the campus resource library, and determine the scheme that can be implemented in the research, so as to provide sufficient factual basis for the research.

Action research method: Through the construction and application of school digital teaching resource library by members and school teachers, teachers can constantly improve and develop themselves in the construction, thus promoting the construction of school digital teaching resource library. We focus on the practice and improvement at the same time, so as to combine theory with practice.

5.2 Research Steps

The first stage: investigation and research, establishment of leading group, division of labor in place layout strategy stage. The leading group of the school information construction is headed by the school principal, with other leading group members as deputy team leaders, and the school office director, scientific research department director, educational administration director, student department director, general affairs director and backbone teachers as members. Members of the group have a clear division of labor, responsibility to people, comprehensive guidance, supervision and inspection of school information construction and application, and gradually discuss the next implementation plan in the implementation process, which plays a key role in promoting our school information.

The second stage: hardware preparation and network construction stage. Hardware preparation, network construction. In 2016, the school fully realized the important role of IT application in education and teaching, and continuously increased investment. The school has two multimedia network computer rooms for students, with 110 computers and 36 classes, which can complete the teaching tasks of information technology courses. In 2016, with the great help of school leaders and the bureau, all the classrooms were equipped with interactive electronic whiteboards, and all grades have realized network class communication. In 2017, a full-automatic recording and broadcasting room was built, which will provide a good platform for teachers' teaching research. In 2018, the software construction was rolled out in place, and all the latest updated Schiavo software was installed in the classroom, realizing the integration of class multimedia teaching.

Broadband access to all ordinary classrooms and all offices, realizing full coverage of campus network. In 2017, the effective management and network security monitoring of the whole campus network were realized. Campus network system, precision recording and broadcasting room, automatic digital campus broadcasting sound system, etc. are designed in place. The computer management system of books is complete, the network management system of laboratory equipment is applied, the electronic reading room of students normally provides 64 safety monitoring points for students' reading and school, and completes the docking with the education metropolitan area network. These kinds of equipment provide powerful support for the management of schools, the education and teaching activities of teachers and students, and the implementation of the new curriculum reform. Electronic management of school property, educational administration and student status is realized. In order to enrich teachers' vision and concept of modern educational information, the school often holds classes on IT application in education sector, such as inviting university professors and experts to give lectures in our school, and sending teachers to study in many other places, which promotes the development of school teachers' information specialty. The school attaches great importance to the construction of campus website, which is regarded as an important basic project to meet the information teaching environment and a facility for teachers and students to successfully receive modern distance education.

The third stage: the stage of ideological transformation and the establishment of teachers' information concept. Teachers' information education and training in our school is first of all the change of teachers' learning concept of information technology. Teachers should establish modern teaching concepts and master modern teaching methods, and change from teaching in the traditional sense to self-learning practitioners. For example, some teachers are accustomed to a three-foot platform and a few pieces of chalk in the teaching process. When the school has carried out a comprehensive reform, the platform has become an audio-visual equipment and chalk has become a whiteboard pen, they are a little unable to adapt for a while. They think that students study for exams, so it is imperative to change teachers' concept of information-based learning. Every semester, our school organizes and trains school teachers to learn information technology, and sets up Information Technology Tuesday Forum training to deepen teaching application. At present, teachers in our school have been able to apply information technology to daily teaching activities. The combination of centralized training and autonomous learning has been carried out according to the situation of each teaching and research group in our school, and good results have been achieved.

The fourth stage: the construction and preliminary application stage of school resource pool platform. The main task of this stage is to find a digital teaching resource platform suitable for schools. The construction of school resource library has mainly gone through three stages. The first stage is to use FTP stage to establish a certain space for each teacher to upload and download digital resources for teachers. There are some disadvantages in the use process, that is, it is not conducive to the sharing of resources among teachers. After that, the implementation of excellent education classes, The construction of class-class communication and school-school communication has promoted the construction of school education digital resource library, Teachers can share resources on one platform, At the same time, it has changed the way teachers attend classes to a great extent, Great changes have taken place in teachers' thoughts and behaviors at this stage, But problems follow, Banbantong is a convenient and quick use based on the network, It is time-consuming and laborious for teachers to surf the Internet, log in and look for resources in class. It is not so convenient. At the school level, teachers' resources cannot be conveniently called in the background. The resource capacity is only 40 GB, which is very small for the construction of the whole school's digital resource library. Therefore, the school still needs to find a convenient and suitable school-based digital teaching resource library platform. In the third stage, Moodle platform can give full play to the potential advantages of campus network, so that teachers and students can rely on network resources to carry out more flexible and richer teaching activities, and enter the stage of construction and application of digital teaching resource library.

The fifth stage: the training stage of resource pool construction scheme formulation and supervision and use. School information construction is mainly responsible by the scientific research department, with full-time information technology teachers responsible for the construction and planning of school network. Other teachers cooperated vigorously to establish and improve various modern educational technology management systems, such as Guilin Dezhi Foreign Language School Resource Library Construction System, Computer Room Management System, Multimedia Classroom Management System, Audio-visual Equipment Management System and various special classroom management systems. The school incorporates information technology into the annual teaching performance assessment, which is linked with the evaluation and promotion of professional titles, which greatly mobilizes the enthusiasm and initiative of teachers to participate in IT application in education sector, thus effectively improving the efficiency and management level of school IT application in education sector.

The sixth stage: the preliminary application and practice stage of school teaching digital resource library. Through the construction of the resource pool by the main members, In the form of instructions issued by the leadership and participation of all employees and parties to jointly build a curriculum resource library, After one year, the resource pool basically covers the knowledge points of various disciplines, Then, in the form of assigning holiday homework, teachers take the task, and upload and share four contents of the resource library, namely, instructional design (WORD), classroom teaching (PPT), chapter test and micro-lesson video [5], so as to promote the application of courses with the construction of knowledge points, promote the use of teachers with administrative requirements, and accelerate the use of digital teaching resource library by teachers with corresponding systems (Table 1).

Table 1. Resource Pool Teacher Building and Usage Feedback Form

Teaching and Research Group	Construction of Library	Application and Feedback
Chinese	Grade Seven to Grade Nine Knowledge points are fully covered	There are various classes and novel learning methods, but students should learn how to screen and use resources
Maths	Grade Seven to Grade Nine Knowledge points are fully covered	The application of mathematics in resource database focuses more on building a powerful question bank, rather than uploading knowledge points and test papers
English	Grade Seven to Grade Nine Knowledge points are fully covered	There are many subject teaching platforms, and the use of campus resource pool is low

(*continued*)

Table 1. (*continued*)

Teaching and Research Group	Construction of Library	Application and Feedback
Physics	Grade Eight and Grade Nine Knowledge points are fully covered	The elements of spreading knowledge in teaching resources are carefully designed and arranged, Most of the resources can present and transmit the information related to the realization of teaching purpose in a clear and effective way in a short time, providing students with direct, indirect and more representative concrete experience, which is greatly beneficial to students' understanding and memory and achieves better teaching effect. If each student can have a computer, I believe the platform will be more efficient
Chemistry	Grade Nine Knowledge points are fully covered	
Biology	Grade Seven and Grade Eight Knowledge points are fully covered	
Politics	Grade Seven to Grade Nine Knowledge points are fully covered	In order to make resources more efficient, The construction of school resource library focuses on the construction of teaching courseware, However, some courseware blindly pursue big and complete, and want to put the best teaching ideas, teaching models and teaching strategies into a complete courseware, hoping to meet the teaching requirements of all teachers, which leads to the problems of insufficient universality, poor flexibility and openness
History	Grade Seven to Grade Nine Knowledge points are fully covered	

(*continued*)

Table 1. (*continued*)

Teaching and Research Group	Construction of Library	Application and Feedback
Geography	Grade Seven and Grade Eight Knowledge points are fully covered	The course meets the needs of teachers in preparing lessons and exchanges experiences in the process of using it. However, due to the single resources of small subjects, the click-through rate is not high
Information Technology	Self-built course	Have a mature curriculum system, and be able to teach smoothly with students
Art	The requirement of syllabus is comprehensively covered	The courseware and instructional design uploaded by teachers in the resource library can be downloaded, which has certain reference significance. However, due to the consideration of their own interests, some teachers may be reluctant to transfer their knowledge or have reservations, and hope that schools can introduce corresponding incentive mechanisms
P.E	The requirement of syllabus is comprehensively covered	
Psychology	Self-built course	
Science	Self-built course	
Calligraphy	Self-built course	
Lesson Preparation	To be continuously perfected	It is well applied

The seventh stage: the summary stage. For the school, the construction of digital teaching resource library will be spread out, and administrative forces will be used to promote the construction and application of resource library, and policies will be established and performance calculation will be included. By using feedback, Teachers also need a lot of online resources to expand the teaching content in courseware making, micro-lesson making and test paper grouping. Therefore, in addition to school-based resources, the school can buy a rubber net resource library to facilitate teachers to give personalized questions, and establish a Schiavo school platform on the network, forming a diversified educational digital resource library system with our school characteristics [5].

6 Conclusion

This study promotes the construction of the school's digital teaching resource library from one aspect, makes teaching develop in the direction of digital, plays a role in drawing on the digital construction of schools, and on the other hand, promotes the transformation of teachers' teaching thinking, from traditional teaching to digital teaching, so as to realize the ideological transformation of digital teaching. Under the general trend of informatization, the construction of digital resource libraries helps to promote the integration of curriculum design, optimize subject settings, promote the deepening of teaching reform, teach according to talents to achieve the purpose of teaching and learning, and enhance the school's social service capabilities.

The temporary conclusion of a research does not mean the end of research activities, but the beginning of popularization and application, because the purpose of research is for practical application. The foothold of our "Research on the Construction and Preliminary Application of Digital Teaching Resource Library in Schools" should be to design and establish a shared resource library suitable for the actual needs of school teaching. If we continue to deepen, we should also turn the curriculum into research results. After transforming the research results into teaching resources, we should do a good job in the dynamic management of the resource library, continue to supplement, improve, modify and update the teaching materials of the resource library, and keep them scientific, advanced, practical and complete, hoping to play a role in attracting jade for the construction of the resource library in other schools [6]. Some scholars [7] argue that this idea of multidisciplinary, interdisciplinary knowledge built in the same database is also known as the deep education. We agree so.

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Analysis and Prediction of the Factors Influencing Students' Grades Based on Their Learning Behaviours in MOOCs

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Abstract. The outbreak of COVID-19 brought new challenges to learning and teaching, and MOOCs (massive open online courses), as online distance learning platforms, provide new opportunities for teaching and learning activities. However, student learning efficiency is difficult to ensure in distance learning. Researchers have studied the relationship between students' grades and behaviours such as forum participation and video viewing; however, less research has been performed on students' submission behaviours. In this paper, we investigate the influence of learning attitudes reflected by students' submission behaviour and the trend in attitude change on grades. First, by studying students' submission behaviours, we identify new features that affect students' grades, such as students' resubmission behaviours. Second, we define positive attitudinal trends that students possess through student behaviour studies: more adequate code, more page viewing actions, and more aggressive submission details performance. Finally, we use the selected features to predict the students' performance. In the experiment, we predict student performance with an accuracy of 86.48%. This study will help teachers understand students' attitudes based on student behaviours and identify students who are struggling academically.

Keywords: massive open online course · learning behaviour · learning initiative · performance prediction

1 Introduction

The development of MOOCs (massive open online courses) supports students learning through online distance learning methods; however, it is difficult to ensure students' learning efficiency in distance learning [1, 2]. Researchers have studied students' behaviours and attitudes towards online learning and have tried to identify students who have academic difficulties [3, 4] . Wu [5] and Liao [6] showed that learners who actively participate in online discussions and watch instructional videos in their entirety usually

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have satisfactory grades. In contrast, students who navigate the course with less action, barely interact with others, and plagiarize assignments usually receive lower grades [7, 8]. Previous behavioural analyses have focused on course activities, after-school learning, and collaboration with others, with less research on students' behaviours in completing assignments. In this paper, we analyse students' learning attitudes and identify academically challenged students based on their behaviours on online programming assignments. The contributions of this paper are as follows: first, we find that certain features correspond to students' positive learning attitudes and significantly affect their performance. Second, we also introduce a period series to analyse the behavioural attitude trends of different students over different teaching weeks. Finally, we achieve an accuracy of 86.48% in predicting students' academic performance with the extracted features.

The article will be described in the following six sections. Section 1 introduces the research background of this study. Section 2 summarizes the findings of previous studies. Section 3 presents the research questions. Section 4 discusses the data selection and the experimental method. Section 5 presents the analysis of the results of the research problem. Section 6 is the conclusion.

2 Related Works

2.1 Students' Behaviours in MOOCs

Researchers have conducted many studies on student behaviours in MOOCs. Liao [6] found that the main factors influencing the type of learners in a study of four courses on MOOCs were video viewing completion and complete sequences of different activities. Students with high grades typically had higher video completion and fewer completion sequences. Zhao [9] classified students into three categories of low, medium, and high well-being and clarified that students with high well-being prefer to explore courses by themselves rather than study for grades, thus achieving better grades in their studies. Researchers have also investigated the relationship between learning behaviours and learning attitudes. Chen [10] indicated that positive learning attitudes were effective in improving academic performance, which included actively engaging in course navigation as well as forum interaction behaviours. Onah [11] investigated the effect of learning attitudes on achievement in blended learning and showed that high-achieving groups of students are highly motivated, so they can effectively regulate their self-learning skills and improve their understanding through continuous postclass communication and group discussions.

2.2 Prediction

Regrading the selection of algorithms for achievement prediction models, researchers have studied various classification prediction algorithms, such as multiple regression models [12], neural networks [13], and decision tree [14], and conducted comparative analyses of model accuracy. Er [15] predicted the performance of 4358 learners by SVM and logistic regression, using the RMSE as a model performance assessment metric. The experimental results showed that SVM provided the optimal model performance, with an accuracy of 93%. Similarly, Huang [16] stated that if teachers need to predict students' academic performance by multiple variables, among multiple linear regression, MLP, and SVM, the SVM model should be chosen because it has the highest PAP among these four models. Injadat [17] and Migueis [18] compared SVM with ensemble learning and showed that ensemble learning was more accurate. Injadat [17] chose two-course stages of student performance, 20% and 50%, to predict the final student performance through SVM, linear regression, and bagging learning methods. The evaluation model metrics were the Gini index and p-value. The ensemble model was found to be more accurate in predicting both stages than any of the individual algorithms. Migueis [18] reported that by comparing algorithms such as SVM, naive bayes and random forest, it was found that random forest could achieve an accuracy of 96.1%. However, naive bayes had the worst prediction. However, Chen [19] proposed that naive bayes performed best in predicting the group of at-risk students in terms of achievement. The above related studies reveal that the results of the prediction models are influenced by the selection of features, assessment metrics, and study context. Therefore, the creation of prediction models requires the selection of suitable feature variables and assessment indicators. In this study, accuracy and recall will be used as the basis for model performance assessment; four prediction algorithms, namely, random forest, MLP, SVM, and naive bayes, will be compared; and the most appropriate algorithm will be selected as the final achievement prediction model for this study.

3 Research Questions

QUESTION A: What behaviours of students can have an impact on grades?
QUESTION B: How do student behaviours change over time?
QUESTION C: How can student grades be predicted through student behaviours?

4 Data and Method

4.1 Data

The data for this study came from 1006 students in a *C Programming Language* course. These students came from more than 10 faculties, including the School of Computer Science, the School of Mathematics and Statistics, and the School of Management and Economics. The average age was 18 years old (the youngest age was 16 years old, and the oldest age was 21 years old), and students were concentrated in the freshman year, with a male to female ratio of 10:3. Additionally, the data of this study were anonymized so that students' personal privacy was ensured. A total of 13 submitted features about students were extracted as the focus of this study, as shown in Table 1. The 13 features can be classified into three categories: Action, Detail, and Code.

Table 1. Features and Their Explanation.

Category	Feature	Explantion
Action	assign	Number of viewing programming assignment
	attempt	Number of attempts to answer questions before submission
	history	Number of viewing submission history
	reports_best	Number of viewing excellent program
	reports_detail	Number of viewing details of the submitted program, including completion time, codelines and codesize, and result of judgement
	result	Number of viewing programming results
	submit	Number of viewing code submission
	user report	Number of viewing submission reports, including the number of submitted programs, the number of passes, the number of successful compilation and so on
Detail	resubmitcountafterAC (resubmit)	Number of times the student resubmitted after "Accept"
	submit_avg_time (avg_time)	Average time for students to submit assignments
	submit_rank (rank)	Average submission ranking of students
Code	sum_codesize (codesize)	Total code size submitted by students
	sum_codelines (codelines)	Total code lines submitted by students

Action refers to the eight submission—related behaviours in the submission log(assign, attempt, history, reports_best, reports_detail, result, submit, user_report). The total number of students in each group is labelled as $LableUser[j_u]$, and the total number of actions is labelled as $LableAction[j_a]$. The average number of behaviours of students in each group is calculated by Eq. (1). It can provide data support for the subsequent establishment of an analysis model.

$$M_{action} = LableUser[j_u]/LableAction[j_a] \tag{1}$$

Detail refers to the behaviours of students at the time of submission, which is more like the unconscious behaviours of students. *Submit_avg_time* indicates the average completion time of students in a certain programming topic; this feature can reflect the seriousness of students regarding the completion of the assignment. *Submit_rank* represents the submission rank of students. By extracting the earliest submission record of students for each programming topic, we can determine the submission rank of students in a certain programming topic, which can reflect their active submission behaviour. *ResubmitcountafterAC* represents students' resubmission behaviour after "Accept". There are 8 types of submission results for programming questions, including AC(Accept), WA (Wrong Answer), and CE (Compile Error). However, only when the submission judge result is AC is the programming topic passed. We look up the submission sequence corresponding to the submission time when the student passed the program and compare it with the total number of submissions of the student to determine whether the student has the behaviour of resubmitting after AC.

Code refers to the total amount of code submitted by the student when the first judge result of the programming assignment is AC. C_{size} is defined as the total code size submitted by students, C_{line} is defined as the total number of lines of code submitted by students, $U_X (1 \leq x \leq 1006)$ is defined as the number of students, and $P_y (1 \leq y \leq 72)$ is defined as the number of programs. An analytical model is constructed by calculating the average code size and the average number of code lines for students in each grade band to explore the correlation between the amount of code and grades.

$$\overline{X}_{size} = \frac{1}{U_X} \sum\nolimits_{x=1,\, y=1}^{n} \left(C_{size_{U_x P_y}} \right) \tag{2}$$

$$\overline{X}_{line} = \frac{1}{U_X} \sum\nolimits_{x=1,\, y=1}^{n} \left(C_{line_{U_x P_y}} \right) \tag{3}$$

4.2 Method

4.2.1 Method of Question A

Students' different behaviours will affect their performance. In this part, features extracted from the data processing part are used to establish the RFECV feature selection model based on random forest. After the fitting of random forest feature attributes, feature attributes are divided according to the importance degree, and the weight value will be given. The weight value represents the influence of each attribute on the label attribute. The larger the weight value is, the greater the influence is, and the smaller the weight value is, the smaller the influence is. Therefore, the weight value also represents the importance of each attribute to the accuracy of prediction. As shown in formula (4), $Weight_i$ is the weight of the i^{th} features and sum of all features' weight adds up to 1 [23]. In addition, this study establishes the correlation between 13 features and students' grades and explore the behavioural differences of students with different grades.

$$\sum\nolimits_{i=1}^{n} Weight_i = 1 \tag{4}$$

According to the influence of students' behaviour on performance, we define the behaviour that has a positive impact on performance as a positive learning attitude, and the behaviour that has a negative impact on performance as a negative learning attitude. Positive learning attitudes include: more adequate code and more page viewing actions, such as reviewing past assignments, and reviewing excellent programming programs; more aggressive submission behaviour, such as earlier assignment submission, repeated submission after "Accept".

4.2.2 Method of Question B

The change trend of different students' behaviour is different. We can distinguish students with different grades through the change trend of behaviour. The opening time of programming questions is mainly from week 4 to week 19 of the teaching week. The average number of repeat submitters in the 16 teaching weeks for groups of students with grades below 50 and above 80 is calculated. The learning attitudes of students in different grade groups throughout the semester are judged. Through the comparative analysis of the average number of students resubmitting in 16 teaching weeks, the influence of students' attitude change trend on their grades is explored.

4.2.3 Method of Question C

In this part, four models, naive bayes [20], MLP [21], SVM [22], and random forest [23], are developed to predict students' performance by extracting 13 behavioural features of students. The final results are compared and studied to find the most appropriate model for predicting performance. Since the median value of the student score band is 82, a score of 80 can minimize the difference in data volume between the left and right sides in data splitting. Moreover, this study also trichotomizes the data by 75 and 90 grades to further explore the impact of student behaviour on student performance. The prediction performance is judged by the following metrics: accuracy and recall. Accuracy represents the accuracy of the model, and recall represents the percentage of records with positive predictions that are correct.

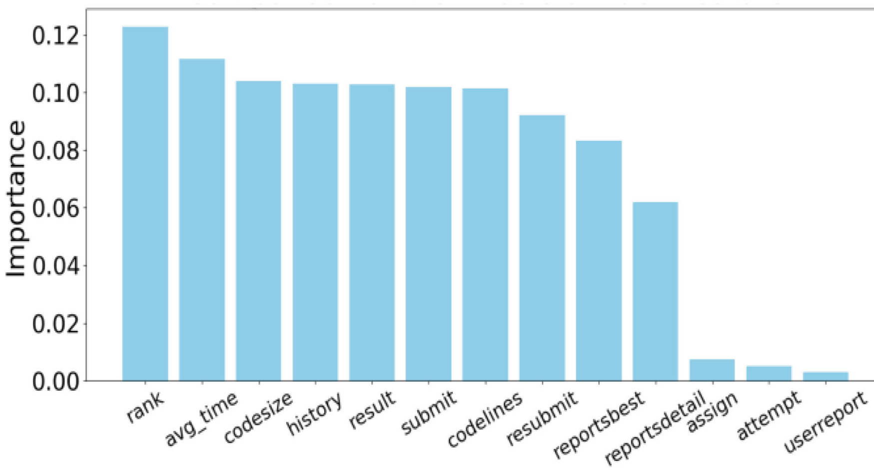

Fig. 1. Comparison of the effects of each feature.

5 Results

5.1 Results of Question A

As shown in Fig. 1, we find that each feature has different feature importance in ranking on grades using RFECV feature selection on 13 features. Of the 13 features that had the most impact on performance, submit_rank (rank) scores 12%. The effect of user_report on performance is only 0.3%.

Then, we analyse the features by categories. Figure 2 shows that students' performance is positively correlated with the average number of actions among the 8 behaviours involved. Especially in the behaviour of *reports_best* (Fig. 3), the frequency of this behaviour tends to be 0 for students with grades below 20. Therefore, it is clear that students who have higher grades pay more attention to their past assignment performance and have more interest in viewing the excellent program examples, which indicates a positive attitude towards the course.

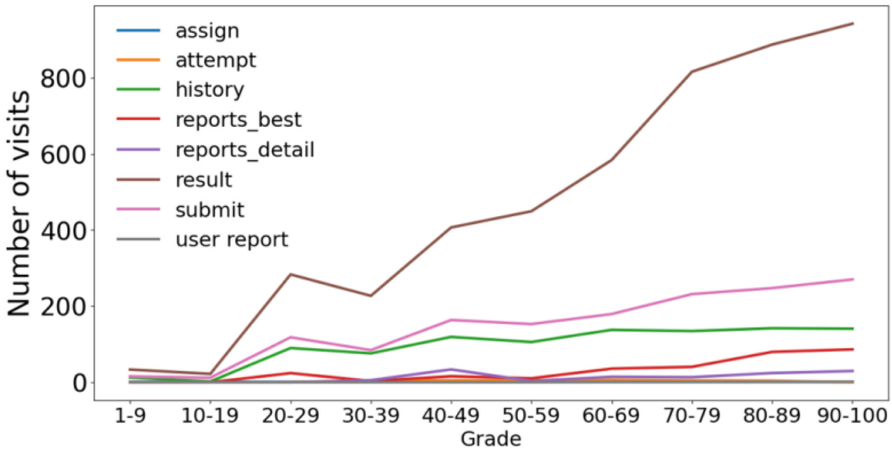

Fig. 2. Relationship between action and grade (8 actions).

As shown in Figs. 4, 5, and 6, the number of resubmissions and the average submission time are positively correlated with the student's grades; that is, students with higher grades are more willing to submit repeatedly and spend more time studying the problems, thus demonstrating their desire to explore. From the submission ranking, grades and the submission ranking show an inverse trend, indicating that students with higher grades prefer to submit programming assignments earlier rather than submit the work in a hurry before the deadline. The earlier submission means that students have more time to prepare, and the rest of the time could be used to find new solutions or preview the new curriculum, also illustrating how students attach importance to assignments.

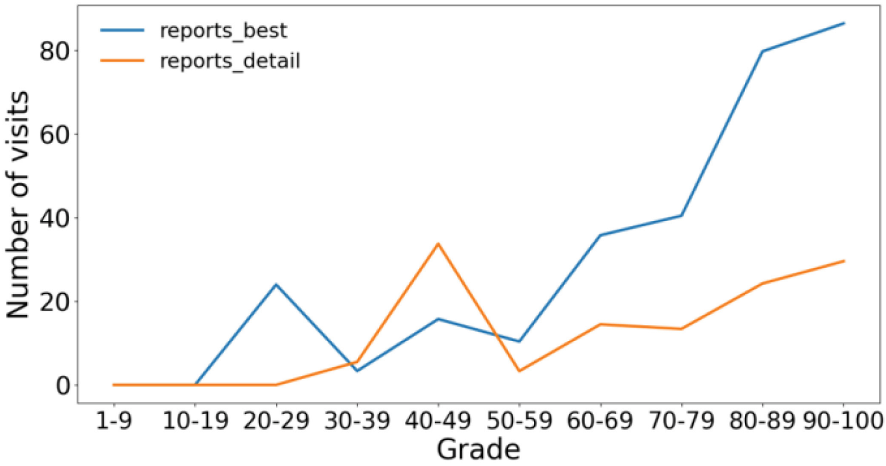

Fig. 3. Relationship between report_best times and report_detail times and grade.

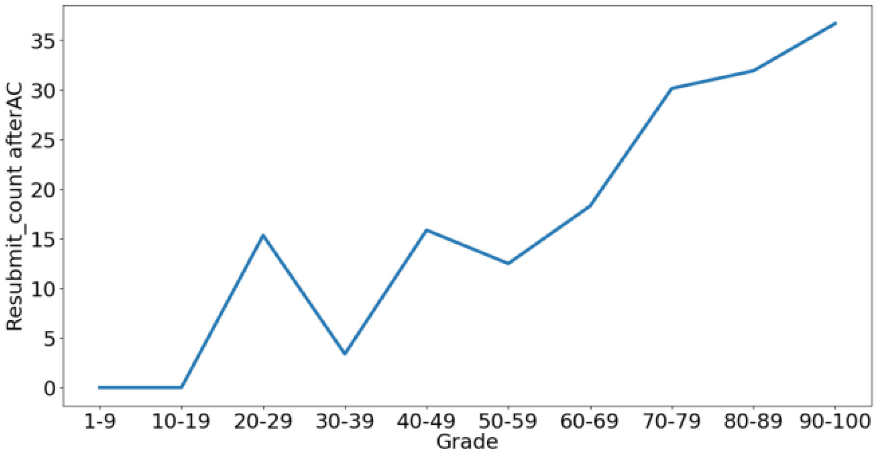

Fig. 4. Relationship between resubmit and grade.

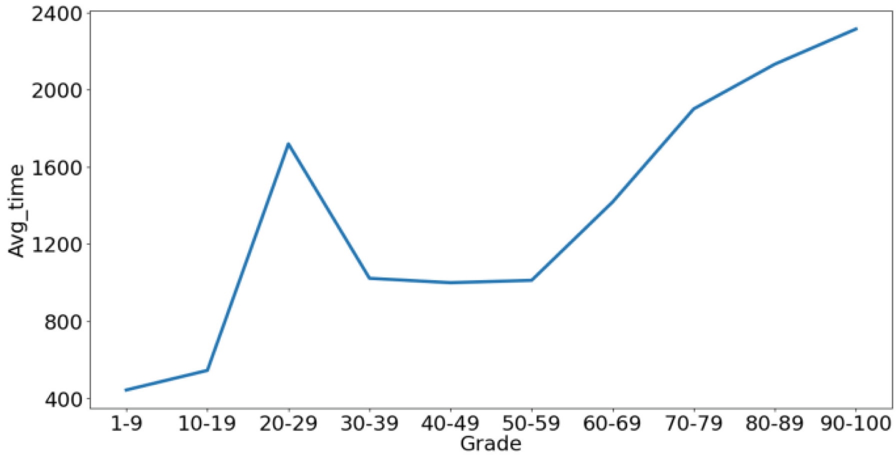

Fig. 5. Relationship between average time and grade.

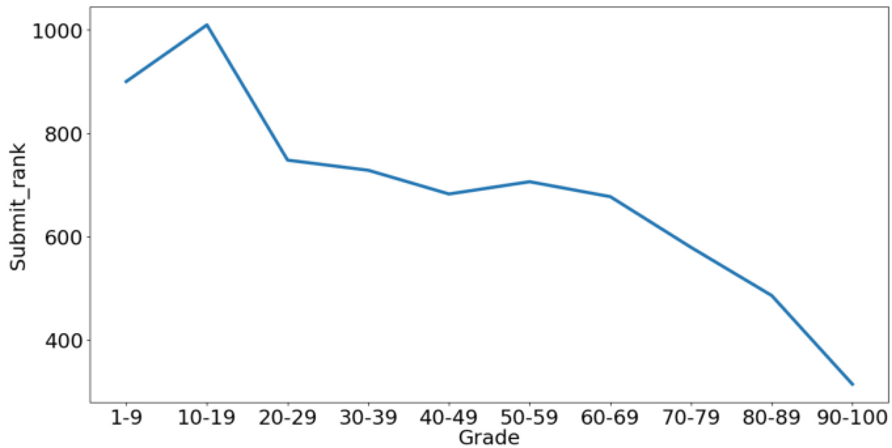

Fig. 6. Relationship between submission rank and grade.

In the analysis of the Code class, we select 66,000 code records of students passing the first time from 191,180 student submission records to analyse the difference in the amount of code in different grades. As shown in Fig. 7, codelines and codesize are positively correlated with grades as grades increase gradually. This means that students with higher grades submit more code. To some extent, the amount of code reflects students' understanding of the programming courses. Although brief codes are more efficient and take less time, they are more demanding for students' logical capabilities. However, most of the students choosing this course are freshmen and do not know much about programming before having this course. Therefore, a larger amount of code could enhance the readability of code and thus help them establish better logic of programming.

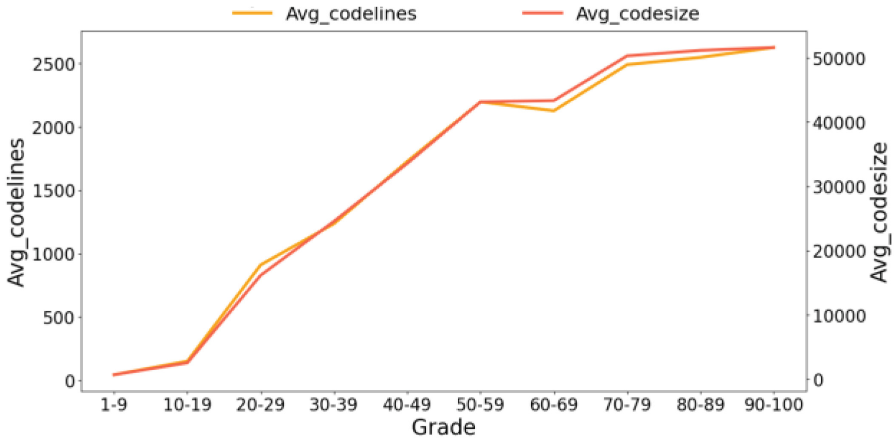

Fig. 7. Relationship between code (size & lines) and grade.

Through the above analysis, students' learning attitude can be judged according to the three types of behaviours: Action, Detail and Code. Positive learning attitude includes: 1) More viewing actions (assign, attempt, history, reports_best, reports_detail, result, submit, user_report); 2) More aggressive submission details, including earlier submission of assignment and more repeated submission behaviour after "Accept"; 3) More accurate code, including more codelines and codesize.

5.2 Results of Question B

Through the analysis of the two trend axes (Fig. 8), it can be seen that the number of repeat submissions of students with more than 80 points fluctuates with the change in teaching week; however, it basically tends to be stable. For the group of students with grades below 50, the number of students who choose to submit repeated that decreases with time, and the whole curve shows a downwards trend. Therefore, for the group of students with high grades, their learning attitudes will not change greatly with time. However, for the group of students with low grades, their learning attitudes will gradually become less positive over time.

5.3 Results of Question C

We use relevant features to predict students' performance through relevant methods of machine learning. Through the analysis and comparison of the four algorithms in Table 2, it is found that the accuracy and recall of random forest are better than those of the other algorithms. Among the binary classification method with 80 as the classification standard, the accuracy of random forest is 86.48%, and the recall of prediction for students with fewer than 80 points is 81.28%. For students above 80 points, the prediction recall is 90.79%. For the three-way classification, although random forest has a higher accuracy of 74.06%, its performance is unsatisfactory compared with that of the binary classification method. In the three-way classification, the number of students is divided

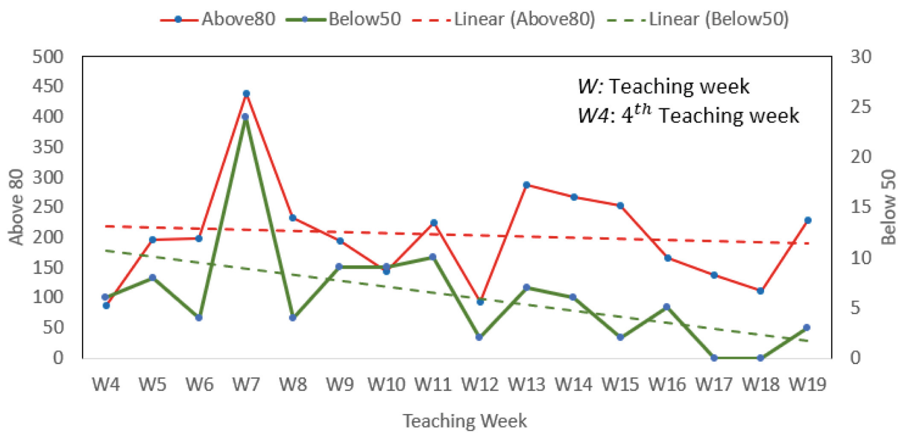

Fig. 8. Relationship between number of re-submitters and teaching week.

into three equal quantity according to the grades of 0–75, 75–90 and 90–100, which can ensure the balance of data quantity, nevertheless, because the average behaviour times of students with scores of 75–90 and 90–100 are not much different, the learning effect of the model is not ideal and the accuracy is not satisfied. Moreover, this part also introduced the five-fold cross validation model to verify and analyse the accuracy of the model, and the result indicated that the accuracy of random forest was the highest, reaching 80.00% ± 8.66%.

Table 2. Binary Classification.

Binary Classification				
Classification		Accuracy	Recall	Cross Validation
SVM	below 80	78.23%	75.77%	77.13% ± 3.13%
	above 80		80.25%	
Naive Bayes	below 80	75.55%	77.97%	74.84% ± 5.11%
	above 80		73.55%	
Random forest	below 80	**86.48%**	81.28%	80.00% ± 8.66%
	above 80		90.79%	
MLP	below 80	76.64%	83.26%	77.43% ± 4.32%
	above 80		71.20%	

Table 3. Three-way Classification.

Three-way Classification				
Classification		Accuracy	Recall	Cross Validation
SVM	below 75	60.23%	63.11%	60.03% ± 1.48%
	between 75 and 90		56.81%	
	above 90		61.59%	
Naive Bayes	below 75	60.14%	82.01%	59.34% ± 5.04%
	between 75 and 90		35.48%	
	above 90		68.51%	
Random forest	below 75	**74.06%**	68.90%	68.29% ± 7.05%
	between 75 and 90		82.78%	
	above 90		68.17%	
MLP	below 75	62.62%	73.48%	59.44% ± 4.52%
	between 75 and 90		50.13%	
	above 90		67.13%	

6 Conclusion

This paper studies the relationship between student behaviour and grade on MOOC platform. By analysing the influence of 1006 students' behaviour in *C language programming* on their grades, this paper identified three behavioural features of students with positive attitude: high behaviour frequency, excellent performance in assignment submission behaviour details, and a large number of code specifications submitted. In addition, the resubmission behaviour of students after "Accept" is analysed in the period dimension, and the analysis finds that for students with high grades, their repeated submission times did not change significantly over the whole semester, and their learning attitudes remained stable. However, for students with low grades, over time, their repeated submission times decreased, and their learning enthusiasm gradually decreased. Based on the above 13 students' behavioural features, the students' academic performance is predicted and analysed. The experimental results show that the accuracy of random forest is the highest, reaching 86.48%.

Although this paper studies the factors of programming assignment submission that affect students' performance, the accuracy and recall of the prediction model can be further improved. We will study more students' submission behaviours in the future, including the detailed analysis of the compiled codes submitted, so as to improve the prediction effect of the overall model.

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On English-Chinese Machine Translation Evaluation in Translating Attributive Clauses in Scientific Texts

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Abstract. As a formal style, English for Science and Technology (EST) has characteristic of preciseness and terseness. For this reason, various clauses, especially attributive clauses, are often used in EST texts. Attributive clauses account for a large proportion of long sentences in EST, and cause difficulties in EST translation. The new generation of neural machine translation (NMT) has been greatly improved in translation quality, but it still has problems in translating English attributive clauses into Chinese. As a new branch of linguistics, language typology aims at describing and explaining the commonness and structural diversity of languages. It provides a new perspective to evaluate the quality of machine translation (MT) of attributive clauses in EST. This paper selects a certain proportion of examples from EST textbooks to make a comparative analysis between Google MT and manual translation under the guidance of linguistic typology. The goal of this paper is to enrich the existing research on EST translation in theory, to inspire translators to predict and correct possible errors in the output, and finally to improve the accuracy and efficiency of MT.

Keywords: Scientific English texts · attributive clause · linguistic topology

1 Introduction

Machine translation (MT) is to translate one natural language text into another or more natural language texts by computer [1]. And there are different criteria for evaluating the quality of MT. Because English for Science and Technology (EST) is required to be objective, concise and accurate [2], clauses (especially attributive clauses) are often used to connect parts of sentences to make the expression detailed and clear. This feature of EST brings challenges to the evaluation of the quality of MT. Linguistic typology refers to analyzing, comparing and classifying languages according to their common structural features and forms, and finds out the similarities and differences between different languages [3]. According to the nature and function of neural machine translation (NMT), linguistic typology provides a new perspective for MT evaluation.

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In order to promote the quality and efficiency of MT and to understand the progress and existing problems of MT in translating attributive clauses in EST into Chinese, this research will evaluate the quality of MT results and answer the following questions:

- Since the error rate of MT has dropped significantly, does the translation result of MT for attributive clauses in EST really satisfy most people?
- In what aspects did MT make progress?
- In what aspects does MT still have problems?

2 Analysis of Attributive Clauses in Chinese and English from the Perspective of Linguistic Typology

Translation Linguistic typology is a new branch of linguistics, whose research scope includes at least: cross-language and typological classification of languages according to word order.

Linguistic typology reveals the commonness of different languages through cross-language comparison, and on this basis reveals the characteristics of each language [4]. One of its characteristics is that the research object must not be a single language, but two or more languages. As Liu Danqing [5] said: "There must be a cross-language (or cross-dialect, cross-era) research perspective before it can be called typology research."

From the perspective of linguistic typology, both English and Chinese belong to SVO languages, that is, sentences in both languages are arranged in the order of "subject-predicate-object". But, due to the fact that English is subordinate to the Indo-European language family and Chinese to the Sino-Tibetan language family, these two languages have their own individuality under the commonness, and the attributive clauses in the two languages are also quite different. It can be seen that English attributive clause is put after the core word, which is helpful to express thoughts calmly, while the descriptive modifiers in Chinese are usually placed before the word being modified [6].

To further understand the differences between Chinese attributives and English attributive clauses, it is necessary to analyze the natures of these two languages. As we all know, there is a fundamental difference between them: "English emphasizes form, while Chinese emphasizes semantics." [7] In general, English sentences often use various means of form to join various parts of sentence, such as joining words, coordinating clauses or subordinate clauses, and paying attention to overt cohesion. English sentences are thus complete in form, compact in structure, and express meaning through form. English grammar is rich in formal markers, which can be embodied in the framework of subject-predicate (object) structure. English compound sentence expanded from this framework has a rigorous structure, many levels of grammar and subordinate relationships. One of the most frequently used clauses is attributive clause. Chinese, in making sentences, seldom use or do not use means of formal cohesion, it pays attention to the logical order of matters and the function and meaning of sentences; sentence components are connected through covert cohesion, which makes the structure concise and lively [8]. The combination of Chinese language units at all levels depends not on morphological changes but on word order. Chinese compound sentences can be divided into two types: joint complex sentences and modificatory complex sentences.

There is no such attributive clause in Chinese like in English, but various phrases that act as attributives, of which the most typical is the structure of “的”. Gu Shunlian [9] defines “的” in Chinese as follows: “的” is a marker of attributive form in Chinese. The Chinese structural auxiliary word “的” has the function of connecting the modifier with the core word to make them a nominal phrase, for example: 小可的娃娃.Of course, not all the modifying relations between attributives and core words are connected by “的”. Whether “的” is used as a structural auxiliary word after the attributive in Chinese is generally related to the nature and meaning of the words serving as attributives and core words, the omission of expression and so on. Some phrases ending in “的” do not play the role of restriction.

To sum up, the basic characteristics of English attributive clauses and Chinese attributives can be contrasted from the following three aspects.

Table 1. Contrast of English attributive clauses and Chinese attributives.

Heading level	Chinese attributives	English attributive clauses
The relative position between attributive (clauses) and core words	Before the core word	After the core word
The marking method	“的”/ gap	Relative pronoun/adverb/complementizer
The referential ways of core words	Gap	Relative pronoun/adverb/gap

3 Assessment Framework

As early as 1993, Yu Shiwen [10] from the Institute of Computational Linguistics of Peking University proposed an evaluation method of MT based on the method of language detection points. The method does not take the whole translation as the evaluation unit, but evaluates the result according to the preset language detection points, so as to make a purposeful evaluation of the MT system. This method is flexible in setting detection points for translation evaluation according to needs.

From the analysis of Chinese attributives and English attributive clauses under the perspective of linguistic typology in the previous section, it can be seen that the most typical conversion rules between English attributive clauses and Chinese attributives should be: changing the word order, converting the structure of “core word + attributive clause” in English into the structure of “attributive + core word” in Chinese, and then adding the complementizer “的” between the clause and the core word. However, in the process of E-C translation, not all English attributive clauses follow typical conversion rules or translation principles. They may sometimes be translated into non-attributive components according to the circumstances. Based on that, and referring to Yu’s translation evaluation method, the relative position between clauses and core words, the marking mode of attributive clauses and the reference mode of core words are used as evaluation points and included in the evaluation criteria. The basic framework of qualitative analysis of the thesis is drawn up as follows:

On the one hand, attention is paid to the conventional conversion of English attributive clauses and Chinese attributives, that is, translate the structure of "core word + attributive clause" in English into the structure of "attributive + core word" in Chinese. On the other hand, the focus is on whether the MT system can smoothly perform some atypical conversions and flexibly translate English attributive clauses into corresponding nonattributive components in Chinese according to the actual situation. Of course, considering that the characteristics of EST are mainly stating facts, being tightly structured and logical, and the translation must be clear in concept, coherent and logical, there are two basic principles to be taken into account when evaluating the translation of attributive clauses in EST, namely, accuracy and fluency.

4 Analysis on Machine Translation Quality of EST Attributive Clauses

In this thesis, example sentences in EST textbooks (including New Introduction to English-Chinese Translation of Science & Technology, Analysis and Translation of 900 Difficult Long Sentences. et.) are chosen as the research object. A parallel contrastive study of MT results and human translation (HT) results is carried out. MT results were generated by Google translate, and HT results came from graduate students and teachers at School of Foreign Languages, Nanchang Hangkong University. This research is divided into two parts: the qualitative evaluation of the MT quality for EST attributive clauses and the quantitative evaluation of its acceptability. Based on previous research, we administered a questionnaire survey to graduate students and teachers of the school of foreign languages, Nanchang Hangkong University (N = 34). A Likert scale with 5 points is used in the questionnaires to gauge their degree of acceptance towards the MT and HT results. Then sentences with low scores and sentences with high scores in MT are analyzed from the perspective of linguistic typology, with the basic characteristics of attributive clauses in English and attributives in Chinese being taken into consideration. The quantitative evaluation is based on the data obtained from the questionnaire survey, and SPSS is used to analyze the acceptability of MT and HT results.

The whole research is mainly divided into three phases: in the preparation phase, the analysis phase and the summary phase. In the preparation phase, the linguistic data collected from the EST textbooks is input into GNMT system to obtain the output. Then the questionnaires are designed, distributed and collected to obtain relevant data. In the analysis phase, a quantitative evaluation of the acceptability of the questionnaire data is made and then a qualitative analysis of the MT results of a certain proportion of sample sentences is conducted. In the summary phase, the translation quality of attributive clauses in EST by GNMT is evaluated.

4.1 Quantitative Evaluation

In the questionnaire distributed, the MT and HT results, together with the original English text, were presented to the subjects for evaluation. To make the subjects pay attention to the attributive clauses as much as possible, the English attributive clauses were highlighted with bold font size. The subjects were asked to rate the Chinese translations. To ensure the objectivity of the survey and avoid potential guidance to the subjects, in the entire questionnaire, there is no hint that half of the translated sentences are translated by Google Translate. The 5-level Likert scale was used to evaluate each group of MT and HT results.

Thirty-four questionnaires are valid. The questionnaire data received is described and processed as follows.

The data described above are worth paying attention to in two aspects: first, the average values show that the acceptability of MT results is lower than that of HT results; second, the standard deviations of acceptability for MT and HT results show that the degree of dispersion of the acceptability for MT results in translating attributive clauses in EST is discretely obvious. In other words, there are great differences between the acceptability of MT results. Some of them are close to HT results while others are very low in acceptability. Comparatively speaking, the standard deviation of the acceptability of HT results is relatively small, which indicates that the acceptability of HT results for translating attributive clauses in EST is relatively balanced and does not fluctuate as much as that of MT results.

In order to verify whether there is a significant difference between the acceptability of MT and HT results, the mean values of the acceptability of the two translations are compared and analyzed by the independent sample T test in SPSS software.As can be seen from Table 3., the observed value of T value is 12.733, and the corresponding 2-tailed probability P value is 0.000, which is less than the significance level of 0.05. It shows that there is a significant difference between the average values of the acceptability of MT and HT results in translating attributive clause in EST.

Table 2. Description of the received questionnaire data

	Machine translation	Human translation
Number of the questionnaire recycled	34	34
Average value	97.37	130.05
Standard deviation	14.63	8.32

Table 3. Independent-sample T test of the MT group and the manual group

Group	Statistic	df	Sig
MT	0.952	43	0.071
HT	0.975	43	0.480

4.2 Qualitative Analysis

Although the acceptability of MT results for attributive clauses in EST are examined from a quantitative perspective, it still remains unknown in which areas it has made progress and in which areas it still has problems. To answer the question, sentences with low scores and sentences with high scores are selected for qualitative analysis.

Analysis for the Sentences with Low Scores

We have seen many chemical changes, from which physical changes are different.
core word relative pronoun attributive clause

Target text: 我们已经看到许多化学变化，物理变化与 物理变化 不同。

Analysis: The sentence structure belongs to the subject-predicate-object structure, in which the attributive clause introduced by “from which” is an inserted non-restrictive attributive clause and aims to explain or supplement the core word “chemical changes”, and the relative pronoun “which” in the clause refers to the core word. This kind of clause is independent in meaning, which is not necessary for the whole sentence, and is actually equivalent to a clause juxtaposed with the main clause. Therefore, its translation can often be separated from the main clause and handled as a coordinating clause. Generally speaking, there are three specific methods of human translation for such clauses: one is to omit the relative pronouns and repeat the core words (used as the subject of the clause); the second is to replace the relative pronoun or relative adverb with pronouns representing the core word (used as the subject of the clause); the third is to omit the relative pronoun and the subject in the clause (that is, neither the core word nor the pronoun replacing relative pronoun is used as the subject of the clause).

It is correct for the MT system to translate the non-restrictive attributive clause into a coordinating clause in the order of the original text and put it after the main clause. However, it mistakenly assumes that the core word of the clause is “physical changes”, converting the relative pronoun “which” to “physical changes” and translating it as the subject of the coordinating clause, resulting in the translation not conforming to the original meaning. The correct way is to translate the attributive clause into a coordinating clause and add the demonstrative pronoun “它们”. The correct translation can be: 我们见过许多化学反应, 它们和物理变化不同.

Source text:The social implications of such automation are profound; they, more

than anything else I have forecast, will shape the community of the future, so I
core word attributive clause
want to turn boldly to make a social prophecy: I believe that the combined effect

of nuclear energy and of automation will be to revolutionize the way in which
core word relative pronoun
men run their industries.
attributive clause

*Target text:*这种自动化的社会意义是深远的。它们比我预言的要重要得多，
attributive
它将塑造未来的社区，所以我想大胆地做出一个社会预言:我相信核能和自动

化的结合效应将彻底改变核能的方式。男人经营自己的产业。
relative pronoun conversion core word independent sentence

Analysis: This sentence is a compound sentence with two levels of meaning connected by the semicolon. The first level of meaning is expressed by the clause "the social implications are profound". The second level of meaning is expressed by a complex sentence whose structure is more complex. Its sentence trunk is "they will shape the community", which contains the comparative adverbial clause "more than anything else" and the attributive clause "I have forecast" which omits relative pronoun. "So" introduces an adverbial clause of result "I want to turn to make a social prophecy" ("to turn to do" means "着手"), in which there is also an object clause "I believe…". The clause of "the combined effect will be to revolutionize…" introduced by "that" is an object clause. And the object of "revolutionize" is followed by the attributive clause "men run their industries" introduced by "in which".

On the whole, most of the structures are correctly handled by MT, but there are major errors in the translation of attributive clauses. This sentence contains two attributive clauses. The first one is the attributive clause "I have forecast", which omits relative pronoun. The MT system identifies this clause and translates it into the form of "attributive + core word"— "我已经预测到的", which is in line with Chinese expression habits. However, it fails to identify the second attributive clause introduced by "in which", and translates the whole object clause into two sentences disconnected from "in which": it falsely reckons that "in which" refers to "nuclear energy", and translates the second half of the sentence into an independent sentence: 男人经营自己的产业. What's more, the translation of "men" is also wrong. In a word, the MT result greatly deviates from the original meaning. The correct translation can be: 这种自动化的社会含义是深刻的; 比起我已经预测到的别的事情来, 它们更能塑造未来的社区, 因此我要大胆的做一个社会预言:我相信核能和自动化的共同效果将会使人类经营工业的方式发生革命.

Source text: The thesis adds that for many victims of genetic disorders, gunshots,

burns and other accidents---transplants can ease or erase the grotesque deformities
core word

that leave them subject to taunts, discrimination, isolation and serious depression.

relative pronoun attributive clause

Target text: 该论文补充说，对于许多遗传疾病，枪击，烧伤和其他事故的受

害者来说，移植可以缓解或消除怪异的畸形，使他们受到嘲讽，歧视，孤立

core word subordinate clause

和严重抑郁。

Analysis:The main part of this sentence is "the thesis adds that for many victims plants can ease or erase the grotesque deformities". In the sentence, the first "that" introduces an object clause and the second "that" introduces an attributive clause which contains many coordinate structures. If the attributive clause is translated into Chinese prepositive attributive, the whole translation will be top-heavy and hard to understand. Therefore, it should be treated as a subordinate clause which can further supplement the main clause. The MT system takes this into account, but because the prepositional objects behind the object complement "subject to" are multiple juxtaposed components, the system has problems in dealing with them. It puts the translation of the attributive clause after the core word "畸形", but fails to express the definite relation between them. The correct translation may be like this:该论文补充道, 对许多遗传疾病患者、枪伤、动物撕咬、烧伤与其他意外事故的受害者而言, 移植可以减轻或消除他们的严重畸形, 使其免受嘲笑、歧视、孤立和严重抑郁.

Source text:That is the reason why the work put out is always less than that put in.

core word relative adverb attributive clause

Target text: 这就是为什么所做的工作总是少于所做的工作的 原因。

adverb attributive core word

Analysis: The trunk of this sentence is "that is the reason" and the main feature of the whole sentence is "core word + attributive clause". The MT system translates it into the form of "attributive + core words", and adds the complementizer "的", which is the correct way to deal with the attributive clause. However, there are some problems in processing the relative adverb "why". The system translates it literally into the corresponding Chinese "为什么", which results in semantic duplication with the core word "原因", and the whole translation reads very awkwardly. To avoid such a situation, the relative adverb should be omitted. Beyond that, the MT system mistranslates both "the work put out" and "that put in" into "所做的", and translate " work" as "工作", resulting in inaccurate translation. The correct translation can be: 这就是输出功总小于输入功的原因.

Analysis for the Sentences with High Scores

Source text:Continuous cropping is a method of farming in which fields are not
core word relative pronoun
given a fallow period between crops.
attributive clause

*Target text:*连作是一种不给田间休耕期的耕作方法。
attributive core word

Analysis: The role of the attributive clause in this sentence is to further explain the specific content of the core word "method of farming". The commonly used method is to translate it into two clauses according to the original order and translate the attributive clause into an appositive clause and add the conjunction "即" before it. The translation obtained is: 连作是一种耕作法, 即在两季作物之间不让土地有休耕期.

The sentence itself is simple, which belongs to the SLP structure. There is no problem in understanding. According to the conventional conversion of restrictive attributive clauses, the MT system converts it into the mode of "attributive + core word" in Chinese and the output is more concise and clearer than the original text. It is a good translation.

Source text:Einstein is a great scientist whose name is known all over the world.
core word relative adverb attributive clause
*Target text:*爱因斯坦是一位伟大的科学家，其 名字享誉全球。
core word pronoun coordinating clause

Analysis: Some non-restrictive attributive clauses are highly restrictive to the core words, and the semantic relationship between them and core words is very close, while the structures of the clauses themselves are simple. In order to make the translation concise and vivid, this kind of attributive clause can often be translated to a phrase, which is put before the core word as attributives, while the whole sentence is still translated into a simple sentence in Chinese. Therefore, HT result of this sentence can be: 爱因斯坦是举世闻名的伟大科学家. The MT system adopts the sequential translation, replacing the relative pronoun "whose" with the pronoun "其" and translating the attributive clause into a single sentence, which basically has no errors in meaning and is also a good translation.

Source text: The most ambitious project so far is a transatlantic fiber-optic cable to be
core word
built by 1988 that could significantly cut the cost of communication between the
relative pronoun attributive clause
United States and Europe.

Target text: 迄今为止，最雄心勃勃的项目是将于 1988年建成的跨大西洋光⊠
core word
这可能会大大降低美国与欧洲之间的通信成本。
pronoun coordinating clause

Analysis: Although some restrictive attributive clauses are connected with the main clauses without commas, they have no restriction on core words in essence, and translating them into independent sentences will not destroy the integrity of the main clauses. There are also some long restrictive attributive clauses. If they are translated as prepositive attributives, the modifiers may be too long to read smoothly. In both cases, the method of sequential translation can be adopted to translate those restrictive attributive clauses into compound sentences. And the relative pronouns or adverbs are translated according to the structural order of the source text. In fact, this is also a way to mutually convert restrictive relative clauses and non-restrictive relative clauses.

The original sentence is a restrictive relative clause belonging to the above situation, and the restrictive attributive clause plays a supplementary role to the main clause. Instead of mechanically translating it into the mode of "attributive + core word", the MT system replaces the relative pronoun "that" with the appropriate pronoun "这" to be the subject of the coordinating clause, and puts the translated attributive clause after the core word, so that the translated text is more flexible and not as lengthy as the original text, conforming to the habit of Chinese.

Source text: Electronic computers, which make it possible to free man from the labor
core word relative pronoun attributive clause
of complex measurements and computations, have found wide application in

engineering.

Target text: 电子计算机使人们摆脱了繁琐的测量和计算工作，已在工程中得到
core word predicate
广泛应用。

Analysis: The attributive clause in this sentence is an inserted non-restrictive attributive clause, which aims to explain or supplement the core words "electronic computers". Generally speaking, this kind of clause is independent in meaning and is not necessary for the whole sentence, so it can be translated into a clause juxtaposed with the main clause. The MT system adopts another completely different method--sequential translation. It omits the relative pronoun "which" and does not use the mode of "attributive + core word" in translation, but flexibly translates the clause and the main clause into a compound sentence introduced by one core word “电子计算机”. The acceptability and readability of MT are no worse than HT results.

5 Conclusion and Future Work

It can be seen from the quantitative results that there are significant differences between the acceptability of MT and HT results of attributive clauses in EST. And the acceptability between MT results is also quite different.

From the results of qualitative analysis(due to the limited space, the analysis of example sentences are not all listed), the progress of MT for translating attributive clauses in EST is reflected in the fact that attributive clauses can be successfully identified by MT system in most cases. And in the process of translation, not only the conventional conversion from “core word + attributive clause” to “attributive + core word” can be adopted, but also some non-conventional conversions can be flexibly handled by MT, such as translating attributive clause into coordinating clause, omitting the core word, translating attributive clause into nonattributive component, etc. So the natural and satisfactory translation outputs are gained. And in these non-conventional conversions, the most commonly used translation method adopted by MT system is the sequential translation.

But according to the linguistic data analyzed, at present, the problems of MT for translating attributive clauses in EST exist in the following aspects:

- When the following phenomena exist in English attributive clauses, problems may occur in conversion: long attributive clauses, core words located in prepositional phrases and constituting a complex logical relationship with other components, multiple juxtaposed components.
- Sometimes, although the attributive clause has been successfully converted, the MT system only mechanically treats the attributive clause from the mode of “core word + attributive clause” to “attributive + core word”, adding the marker word “的”, without considering the structure and the logic of the whole sentence, which results in ambiguous sentence meaning. In fact, it is better to translate English attributive clause into Chinese coordinating clause in some cases.
- Sometimes the semantic meaning of the translated text is not clear enough due to the literal translation which MT adopts.
- In the case of an attributive clause containing other attributive clauses or a sentence containing two or more attributive clauses, at least one of the attributive clauses may be omitted or wrongly translated.
- Whether it is a restrictive attributive clause or a non-restrictive attributive clause, the MT system has encountered identification errors for core words or understanding errors for attributive clause; some methods (e.g. translating attributive clause as conditional adverbial clause or result adverbial clause) can be correctly adopted in translating some sentences whereas mistakes appear in translating other sentences, which shows that GNMT system is not stable enough for the moment.

However, due to the author’s limited technical background, the focus of the research lies in linguistic typology. It is impossible to analyze, evaluate and improve GNMT in a deeper level from the technical level, and to explore what breakthroughs should be made in MT in the future. Meanwhile, the content of the linguistic data studied is limited and the sample size is not large, so the errors that can be found are limited, which may not cover all the problems in the translation of attributive clauses in EST. Researchers should use more linguistic data in the future research, find more common features supported by a huge amounts of data and sum up more translation problems to improve the quality evaluation of MT and provide more suggestions for the improvement of MT in this field.

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A Study on the Interaction Effectiveness of Teacher Discourse in Online Synchronous Elementary and Advanced Oral Chinese Courses

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Abstract. This study attempts to find a way to solve the problem of unsatisfactory interaction effectiveness in online synchronous elementary and advanced oral Chinese teaching, and to provide teachers with effective and intuitive teaching discourse guidance. The number of words output by students is the measure index. Firstly, this study analyzes the differences in the interaction effectiveness between different categories and forms of teacher discourse in the offline elementary and advanced oral Chinese demonstration courses based on the ELAN video annotation tool and Python, and proposes "Six Principles" for the usage of teacher discourse. Then, based on the DingTalk teaching platform, the "Six Principles" was applied to the online synchronous elementary and advanced oral Chinese courses. The interaction effectiveness before and after the application were compared experimentally to verify the effectiveness of the "six principles" suggestion. It was found that after teachers consciously adjusted discourse categories according to the "Six Principles", the teaching interaction effectiveness was improved. The research ideas in this study have reference value for improving the interaction effectiveness of other online synchronous language teaching.

Keywords: Teacher Discourse · Online Teaching · Synchronous Teaching · Interaction Effectiveness · Oral Chinese

1 Introduction

In the digital era under the epidemic, new technologies, new platforms and new methods are constantly emerging, and the online teaching model has become the "new normal" of education. With the continuous development of international Chinese education, Chinese learners are all over the world, and a large number of learners choose to learn Chinese online, which also promotes the normalization of the application of online education in the field of international Chinese education.

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The online synchronous elementary oral Chinese courses and advanced oral Chinese courses (hereinafter referred to as "OSEO course" and "OSAO course") are quite different in terms of teaching objectives and content, and students have high learning needs. Faced with the objective needs of online Chinese learning, various schools and educational institutions generally provide synchronous, asynchronous or mixed synchronous and asynchronous online teaching courses [1, 2]. Among them, online asynchronous teaching is mainly carried out in the form of recording and broadcasting, and teachers and students take courses remotely and have different online hours. Online synchronous teaching is mainly carried out in the form of online live broadcast. Teachers and students take courses remotely but online at the same time, which is more similar to offline teaching. There is synchronous online communication and interaction between teachers and students based on the network platform. However, compared with the interaction effectiveness of offline teaching, the overall interaction effectiveness of online teaching is not quite satisfactory [3].

In constructivist learning theory, teachers are considered as students' helpers and collaborators in the learning process, and teachers provide guidance for students. The help provided by teachers to students is like "scaffolding" to provide support for improving students' abilities. Asking questions and providing help is just one of the means for teachers to provide support and guidance, and teachers' questioning and guidance are mostly done through discourse.

In teaching activities, teacher discourse plays an important role in guiding students' learning [4]. Under the same conditions, different categories and forms of teacher discourses will have huge differences in the number of words output by students. In online synchronous teaching, there are a large number of novice teachers. The ability of different teachers to control teaching discourse is uneven, and the teaching interaction effectiveness is obviously different. Therefore, improving the interaction effectiveness of teacher discourse has a key impact on improving the teaching effect of online teachers [5–8].

This study strives to find out the principles and suggestions for the use of teacher discourse by analyzing the interaction effectiveness of teacher discourse in offline elementary and advanced oral Chinese demonstration courses (hereinafter referred to as "OEOD course" and "OAOD course"), and apply the principles to OSEO and OSAO courses. The application effectiveness is tested by comparative experiments. It is expected that the findings from this study can provide intuitive and effective teaching principle suggestions for teachers of online synchronous teaching, and improve teaching interaction effectiveness.

2 The Analysis of the Interaction Effectiveness of Teacher Discourse in OEOD Course and OAOD Course

2.1 Demonstration Lesson Selection and Analysis Tool Description

Demonstration course teaching is a teaching and research activity that develops teaching to the state of "ideal teaching" in a planned way, and has a distinct guiding role in the application of teaching concepts, teaching methods and teaching modes. Before the demonstration course is launched, teachers have carefully designed the teacher discourse in teaching activities, which play an intuitive display role for other teachers' daily teaching.

In the field of international Chinese education, the studies on teacher discourse mostly focus on the case study of comprehensive courses and the case study on the validity of questioning. Based on the combing of previous studies on teacher discourse in oral Chinese teaching in the past two decades, the existing research on teacher discourses mainly focuses on the following contents, such as the dialogue between teachers and students, the teacher questioning discourses, and the student discourses. Feedback discourses, teacher-student negotiation discourse, teacher instruction discourses, etc. In the study, the classification of teacher question discourses can be divided into reference questions and demonstration questions. Teacher instruction discourses can be divided into three categories, including command discourses, suggestion discourses, request discourses. However, the study that focus on the interaction effectiveness of teacher discourse in online synchronous oral teaching is still insufficient [9–12].

This study focuses on the teaching of elementary and advanced oral Chinese courses. Two videos of Beijing Language and Culture University teachers' demonstration courses are randomly selected for each course. The teaching duration of each video is 60 min. The total video duration of the elementary demonstration course is 120 min, and the total video duration of the advanced demonstration course 120 min.

In the video study of the demonstration courses, the Eudico Linguistic Annotator audio and video annotation software (hereinafter referred to as ELAN) developed by the Max Planck Institute of Psycholinguistics in the Netherlands was used for text annotation. This tool is widely used in language teaching video analysis to build discourse database, and it is also commonly used to carry out multimodal discourse analysis study [13, 14], since this tool enables multi-level labeling of videos. In this study, ELAN will also be used to label the text of the videos and build a database of teacher discourse and student output content texts in demonstration courses, and use Python for data statistics.

2.2 Definition of Teacher Discourse and Explanation of Validity Criteria

The teacher discourse in this study contains all the teaching sentences of teachers in the process of teaching activities. In the process of validity analysis, this study divides the sentences used by teachers into four categories: declarative sentences, interrogative sentences, imperative sentences and exclamatory sentences. The interrogative sentences are further divided into four forms: general interrogative questions, special interrogative questions, selective interrogative questions, and incomplete sentence questions. Among them, incomplete sentence questions refer to incomplete but obviously guiding words spoken by teachers in teaching, such as "Have?", "Then he?". The measure index of teaching interaction effectiveness in this study is the number of words output by students to each category or form of teacher discourse, which is intuitive.

2.3 Definition of Teacher Discourse and Explanation of Validity Criteria

The collection of teacher and student discourse text data in the demonstration course includes video text annotation, statistics of the number of each category or form of teacher discourse, and statistics of the number of words output by students. See the steps below for details:

Step 1: Video text annotation. Import demonstration courses into ELAN and create text annotation layers. During the marking process, all the discourses of teachers and students are transcribed into text, the punctuation at the end of the sentence is strictly used to facilitate the later statistics, and all the transcribed texts were manually checked twice. Export text in.txt format with timecode as a text database for demonstration courses.

Step 2: Annotation of the categories of discourse used by the teacher. In the demonstration course text database, the teacher discourse categories are annotated according to the classification criteria for teacher discourse in this study.

Step 3: Annotation of the forms of the interrogative sentence used by the teacher. In the demonstration course text database, the interrogative sentence forms used by the teacher are annotated according to the classification criteria for the interrogative sentence in this study.

Step 4: Data analysis. Count the number of sentences used in teacher discourse of each category. Then count the number of sentences used in teacher discourse of each interrogative sentence form. Use the "count_word" function in Python to count the number of words output by the students after each category or form of teacher discourse the teacher used.

Statistics are shown in Table 1.

Table 1. Demonstration course overall data.

Duration	Level	Number of teacher discourse	Number of words output by students
120 min	Elementary	1804	8634
120 min	Advanced	706	2097

Through the analysis of the statistics, it was found that exclamatory sentences did not appear in teacher discourse in the demonstration course, so this category was removed from the data table in order to display the data more clearly.

The statistics of the number of each category of teacher discourses and the statistics of the number of words output by students to different categories of teacher discourses are counted.

Statistics are shown in Table 2.

Table 2. Teacher discourse categories and student output words data table.

Category	OEOD course/ Number of teacher discourse	OEOD course/ Number of words output by students	OAOD course / Number of teacher discourse	OAOD course / Number of words output by students
Declarative sentences	888	338	139	269
Interrogative sentences	416	1884	190	1401
Imperative sentences	500	6412	24	427

Interrogative sentences are generally considered to be the most common form of discourse that teachers use during classroom interactions. Further statistics are made on the four questioning forms of teachers' interrogative sentences.

Statistics are shown in Table 3.

Table 3. Interrogative sentence forms and student output words data table.

Form	OEOD course/Number of teacher discourse	OEOD course/Number of words output by students	OAOD course/Number of teacher discourse	OAOD course/Number of words output by students
General interrogative questions	96	254	72	378
Special interrogative questions	184	788	236	2124
Selective interrogative questions	40	84	20	106
Incomplete sentence questions	96	1012	28	194

Based on Table 3, the proportion of each question form in the total teacher question sentence is further calculated, named as "form proportion". Count the average number of words output by students to each form of teacher discourse, named as "words average". Sentences.

Details are shown below (see Fig. 1).

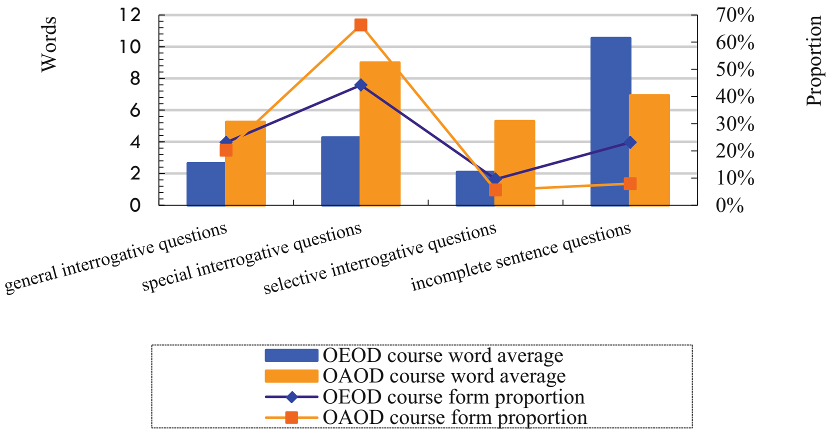

Fig. 1. Form proportion and words average figure.

2.4 Discussion and Analysis

Based on statistical analysis, it was found that in the teacher discourse of the OEOD course, the number of declarative sentences accounted for 49%, the frequency of use was the highest, and the number of interrogative sentences accounted for 23%, the frequency of use was the lowest. In the teacher discourse of the OAOD course, the number of interrogative sentences accounted for 54%, the frequency of use was the highest, and the number of imperative sentences accounted for 7%, the frequency of use was the lowest.

By calculating the average number of words output by students to each category of teacher discourse, it was found that in OEOD course and OAOD course, when teachers use imperative sentences, students output the largest amount of words, followed by interrogative sentences, and when using declarative sentences, students output the least amount of words.

The reasons for the above data are analyzed as follows. According to the principle of anxiety, students will be affected by anxiety when expressing. Elementary students have limited vocabulary, and students tend to be nervous and afraid when they speak. Teachers' use of imperative sentences can better reflect the meaning of euphemism and invite students to try, which can relieve students' anxiety and provide students with encouragement and effective guidance, so that students can output more feedback content. In the meanwhile, compared with elementary level students, advanced students are able to use richer vocabulary which make them feel more confident in their expressions. Imperative sentences are mostly used as instructions in open task activities, which can stimulate students to explore by themselves, collaborate with each other and express freely.

Declarative sentences account for a high proportion of teachers' discourse usage, mainly because declarative sentences are mostly knowledge-explaining discourses. In the teaching process, the explanation of knowledge can provide enough "scaffolding" for students, which is indispensable. However, the interaction effectiveness of declarative sentences is the lowest. Teachers need to make scientific arrangements for the time of knowledge teaching and interaction in teaching according to different levels of students.

For example, teachers can carry out teaching in the flipped classroom teaching mode. Teachers can provide knowledge content materials to students before class, and encourage students to complete the preview by themselves. During the class, teachers can carry out short quizzes first and then explain the key content based on the quinze result. In this way, teachers have more time to interact in class, and increase the use of other types of teacher discourse reasonably to improve the interaction effectiveness with students.

The analysis shows that, both in OEOD course and OAOD course, the most frequently used interrogative sentence form is special interrogative question form, and the least frequently used interrogative sentence form is selective interrogative question form. It is important to note that incomplete sentence questions are used about three times as often in the OEOD course as the OAOD course. In the OEOD course, when teacher use the incomplete sentence question form, students output the most number of words, when using the selective interrogative question form, students output the lowest number of words. In OAOD course, when teachers use special interrogative question form, students output the most mount of words, when using general interrogative question form or selective interrogative question form, students output the lowest number of words.

The reasons for the above data are analyzed as follows. Constructivist learning theory points out that the teaching process needs to be student-centered and teachers should play a leading role. Teachers need to analyze what their students need, to know the level of students Chinese proficiency, and to provide effective support for students to help them build their own knowledge system. According to Vygotsky's zone of proximal development theory, the difference between new knowledge and old knowledge is the zone of proximal development. Teachers should continue to provide guidance for students so that they can make progress step by step, and lead them to achieve deep learning.

In the OEOD course, the reason why the incomplete sentence question form can achieve the best effectiveness of interaction is that teachers can continue to ask further questions in the most concise form based on the feedback content of students. Doing so can guide students to gradually increase the expression content to achieve the best interaction effectiveness. In the OAOD course, special interrogative sentences have the same function as imperative sentences. These two kinds of sentences forms are often used by teachers when they try to organize open-ended tasks. Students can take the initiative to contact their own knowledge system, organize their language, collaborate with others, discuss between groups, reflect to the questions, and express themselves, so as to achieve the best interaction effectiveness.

2.5 Suggestions on Principles of Discourse Usage to Improve the Interaction Effectiveness of Teacher Discourse

Based on the above statistical analysis, it was found that teachers need to follow some teaching principles in the teaching process to guide the usage of their discourse in order to obtain better interactive effectiveness in the teaching process. "Six Principles" were summarized in this study for teacher discourse usage in elementary and advanced oral Chinese course. The principles are as follows.

The Principle of Appropriateness. During the teaching process, the time arrangement of the explanation and interaction content should be scientific and reasonable, so as to achieve “intensive explanations and more practice”.

The Principle of Priorities. In order to improve the interaction effectiveness, teachers should give priority to using imperative sentences in both elementary and advanced oral Chinese courses. In the elementary oral Chinese course, when teachers use interrogative sentences to ask questions, they should use more questions in the form of incomplete sentences, so that students can complete more expressions. In advanced oral Chinese courses, teachers should give priority to using special interrogative questions. Because this form can not only promote students’ expression, but also exercise students’ thinking ability.

The Principle of Diversity. Teachers should use different sentence categories and forms. Although the interaction effectiveness of general interrogative questions and selected interrogative questions is not ideal, occasional use can increase the diversity of teacher discourse forms. However, it should be noted that when using these two question forms, incomplete sentence questions or special interrogative questions should be followed up in time according to the level of students to ensure the interaction effectiveness.

The Principle of Avoidance. When the teaching time is limited, the sentence categories and forms with the best interaction effectiveness should be selected to interact with the students according to the teaching objectives. Avoid using a lot of sentence categories or forms with poor interaction effect, so that the oral course loses its interactive features.

The Principle of Flexibility. “Teaching has a method, but there is no fixed method”. Teaching should be carried out flexibly according to the actual situation. While following the teaching principles, teachers should pay attention to observe the students’ feedback, and adjust the teaching strategies according to the actual situation of the classroom.

The Principle of Metacognitive Strategies. Teachers should actively use metacognitive strategies in the teaching process. In this way, teachers can adjust and control their own teaching discourse at any time, and consciously improve the interactive arrangement of teaching.

3 Comparative Experiments on the Interaction Effectiveness of Teacher Discourse in OSEO Course and OSAO Course

3.1 Experiment Description

In online synchronous teaching, the teaching interaction effectiveness is not ideal due to the influence of distance and network factors. In the teaching process, the choice of the teacher discourse sentence categories and forms have a particularly prominent influence on the interaction effectiveness. In order to test the effectiveness of the above

"Six Principles" on interactivity in online synchronous teaching, this paper conducts an empirical comparative study.

In the comparative test, four classes of online synchronous oral Chinese courses were selected as the experimental objects, 6–9 students per class. The four classes are divided into OSEO course experimental group, OSEO course control group, OSAO course experimental group and OSAO course control group. The teachers of the experimental group and the control group of each level are the same teacher, and the students' learning progress is the same. The online synchronous course teaching platform all uses the DingTalk platform. Total course duration of each level is 120 min.

The experimental procedure is described as follows:

Step 1: Experiment preparation. Before the start of the course, the teachers of the elementary and advanced classes prepared two different course notes for the experimental group and the control group for the same course. The use of teacher discourse in the experimental group handout was adjusted according to the "Six Principles", and the teacher discourse in the control group handout continued the content version used in the previous semester.

Step 2: Video text annotation. Turn on the DingTalk video recording function during the teaching process. After the course, the shorthand function of the DingTalk platform is used to sort out the teachers discourse and the words output by students in the video, all the content will be manually proofread. When proofreading, remove the words of teachers and students regarding equipment or network debugging, such as "can you hear me?".

Step 3: Use Python to count students' output words.

Step 4: Data analysis.

3.2 Experimental Data Comparison Sample

In the following Table, number of teacher discourse is abbreviated as "TD", number of student output words is abbreviated as "SW", proportion is abbreviated as "P", average is abbreviated as "A".

The experimental data of the two groups are shown in Tables 4, 5, 6 and 7.

Table 4. OSEO Course Data Comparison Table (A).

Category	Experimental group				Control group			
	TD	P	SW	A	TD	P	SW	A
Declarative sentences	346	48%	63	0	552	62%	84	0
Interrogative sentences	186	26%	532	3	198	22%	478	2
Imperative sentences	193	27%	982	5	134	15%	606	5

Table 5. OSEO Course Data Comparison Table (B).

Form	Experimental group				Control group			
	TD	P	SW	A	TD	P	SW	A
General interrogative questions	32	17%	37	1	79	40%	123	2
Special interrogative questions	59	32%	116	2	63	32%	177	3
Selective interrogative questions	17	9%	19	1	34	17%	42	1
Incomplete sentence questions	78	42%	360	5	22	11%	136	6

Table 6. OSAO Course Data Comparison Table (A).

Category	Experimental group				Control group			
	TD	P	SW	A	TD	P	SW	A
Declarative sentences	156	35%	232	1	226	47%	187	1
Interrogative sentences	201	45%	1591	8	196	40%	1436	7
Imperative sentences	91	20%	1713	19	62	13%	1123	18

Table 7. OSAO Course Data Comparison Table (B).

Form	Experimental group				Control group			
	TD	P	SW	A	TD	P	SW	A
General interrogative questions	29	14%	222	8	47	24%	301	6
Special interrogative questions	96	48%	843	9	77	39%	672	9
Selective interrogative questions	11	5%	72	7	21	11%	106	5
Incomplete sentence questions	65	32%	454	7	51	26%	357	7

3.3 Discussion and Analysis of Experimental Results

In the OSEO course experimental group, after adjusting the sentence categories of teacher discourse according to the "Six Principles", the use of imperative sentences increased by 12%, the use of interrogative sentences increased by 4%, and the use of incomplete sentence questions increased by 31%.

It was found through interviews that the usage of incomplete sentence questions was a flexible design by teachers in the teaching process based on the content of students' feedback. The overall student output of the experimental group was 30% higher than that of the control group.

In the OSAO course experimental group, after adjusting the sentence forms of teacher discourse according to the "Six Principles", the usage of imperative sentences increased by 7%, and the usage of special interrogative questions increased by 9%. The overall student output of the experimental group was 22% higher than that of the control group.

In the OSEO course and OSAO course, the usage of declarative sentences in the experimental group was 8%–14% lower than that in the control group, and the usage of general interrogative sentences and choice interrogative sentences was lower than that in the control group.

Through the interviews with teachers, it was found that according to "The principle of appropriateness", teachers make full use of the advantages of online platforms to provide students with preview materials, allowing students to use fragmented time for self-study, and reduce the explanation of basic language knowledge in class. This frees up more time for interactive exercises. According to "The principle of priorities and avoidance", teachers will consciously increase the usage of sentences with good interaction effectiveness and reduce the usage of sentences with poor interaction effectiveness. According to "The principle of diversity and flexibility", teachers consciously use imperative sentences and special interrogative questions to substitute each other, which not only ensures the interaction effectiveness, but also avoids the rigidity of sentence categories and forms. In general, teachers in the experimental group will use metacognitive strategies more consciously, and actively adjust their teaching discourses based on student feedback, which significantly improves the effectiveness of teaching interaction.

The overall comparison found that the application of the "Six Principles" to the adjustment of teacher discourse usage in OSEO course and OSAO course has significantly improved the teaching interaction effectiveness.

4 Summary

This study starts from the actual problem that the interaction effectiveness of online synchronous oral Chinese teaching is not ideal. Firstly, it analyzes the differences in the interaction effectiveness of different teacher discourse types in the demonstration courses of offline synchronous teaching, and then summarizes the principles of teaching discourse usage to improve the interaction effectiveness. Finally, the principle of teacher discourse usage is applied to online synchronous oral Chinese teaching, and an empirical comparative study is carried out to verify the validity of the principle.

It was found in this study that the application of "The principle of appropriateness, priorities, diversity, avoidance, flexibility and metacognitive strategies" to OSEO course and OSAO course significantly increased the number of words output by students, improved the teaching interaction effectiveness, and facilitated emotional connection between teachers and students.

Specifically, in the limited time of online synchronous oral Chinese course, it is recommended that elementary and advanced course teachers use more imperative sentences. OSEO course teachers use more incomplete sentences questions. Teachers of OSAO course should use more special interrogative sentences, consciously use imperative sentences and special interrogative questions alternately.

It is hoped that the principles of teacher discourse usage and the specific sentence categories and forms using suggestions in this study can provide intuitive and easy-to-use discourse guidance for teachers in online synchronous teaching, and provide assistance for the improvement of teacher-student interaction in online synchronous teaching.

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A Dynamic Description of Learning Motivation of English Major Cases Upgrading from Junior Colleges to Undergraduates

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Abstract. Based on the second language (L2) Motivational Self System and complex dynamic systems theory, this study used qualitative interview and self narration to describe the dynamic development of English majors upgrading from junior colleges to undergraduates in three periods -- junior colleges, the exam preparation for upgrading from junior colleges to undergraduates and undergraduate universities. The results show that: (1) English learning motivation from junior colleges to undergraduate universities has an upward trend, but it also has fluctuations. (2) Generally speaking, in the three periods these students are mostly influenced by the ideal L2 self; ought-to L2 self plays a decisive role in the junior college period; after entering undergraduate universities, the L2 learning experience also greatly affects students' learning motivation. (3) L2 learning motivation is dynamic and changing all the time, so there are different primary and secondary factors affecting students' L2 learning motivation in different periods.

Keywords: L2 Motivational Self System · Complex Dynamic Systems Theory · English Majors Upgrading from Junior Colleges to Undergraduates · Dynamic Description

1 Introduction

Students' learning motivation from primary school to higher education is highly related to their academic achievement and choices of learning strategies. Most students with English learning difficulties are affected by their learning motivation, such as underestimation of their abilities, low interest in English learning, lack of encouragement from the external environment, etc. Therefore, motivation has a profound and extensive impact on learners' learning, which also shows the significance of the present study on English learning motivation.

As early as the 1930s, motivation theory had become an important research topic in the field of psychology. As a branch of motivation, learning motivation has gradually become a hot research topic in the field of educational psychology. As an important variable, learning motivation plays a key role in foreign language learning behavior and achievement. Therefore, the present study discusses English learning motivation.

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In addition, the research subjects of this paper are a group of relatively special students upgrading from junior colleges to undergraduates.

The concept of lifelong education was put forward by Paul Lengrand of France in the 1960s [1]. Therefore, the rise of a new higher education policy in the history of Chinese education -- upgrading from junior colleges to undergraduates [2], in a sense, is also in response to the concept of lifelong education. In the 1980s, China began to implement the policy of upgrading from junior colleges to undergraduates ("专升本" in Chinese, shortly as "c-u" hereafter) that graduates from junior colleges can be upgraded to undergraduates through the selection examination organized by Provincial Department of Education to continue their two-year full-time education for a bachelor's degree. Of course, the promulgation and implementation of the policy is also to meet the current economic and social development and the needs of junior college students to improve their academic qualifications [2]. However, it is difficult for many undergraduate universities to teach the c-u students with the same methods as for those who directly entered undergraduate universities through the college entrance examination, because the internal and external influencing factors of the two types of students are different in many aspects of learning and life. Therefore, c-u students should be taught according to their aptitudes and characteristics. This study focuses on English learning motivation of c-u English majors. However, there were few researches on it, and the theoretical basis of the previous research was mainly based on the traditional classification of learning motivation. For example, Lu Chunyan (2010) mainly adopted the method of quantitative investigation into English learning motivation of college students [2].

In short, this study mainly focuses on the L2 learning motivation of c-u English majors.

2 Literature Review

2.1 L2 Learning Motivation

Learning motivation is an important factor affecting the success of foreign language learning. It is not only the source power of foreign language learning, but also a driving force in the process of foreign language learning [3]. L2 learning is also a complex process, because in addition to a good language teacher, more elements affecting L2 learning relate to individual differences [4].

The traditional L2 learning motivation was proposed by Gardner & Lambert (1972) as "integrative motivation" and "instrumental motivation" [5]. In recent decades, the research on L2 motivation has mainly focused on the two language learning tendencies or motivation types of "integrative" and "instrumental". "Integrative motivation" refers to the motivation generated for the purpose of integrating into the target language population, while "instrumental motivation" refers to the motivation based on usage value of the language. Higgins divided "instrumental motivation" into two types: promotion (internalized instrumental motivation) and prevention (less internalized instrumental motivation) [6]. However, with the development of the times and the deepening of theoretical research, it seems that there are more and more limitations under the new development trend [3], which can not solve the new problems encountered in motivation research. Yashima (2002) put forward the concept of "international posture", which is an extension and expansion of the traditional concept of “integrative motivation” including the motivation for international affairs, cross-cultural exchange and learning [7]. Compared with the theory of Gardner and Lambert, Yashima’s theory has expanded the research dimension, but there are still deficiencies. Therefore, Dörnyei (2005) proposed L2 motivational self system based on psychological self-concept and traditional L2 motivation theory [8]. Psychological “self-concept” was first proposed by psychologist William James (1890) [9]. Self-concept is the individual’s perception of all aspects of self including three functions, namely, the guiding role of individual behavior, the determining role of self expectation level and the filtering role of new experience [10]. At the same time, the theoretical model under this concept is also developing and improving, from Coop Ersmith’s one-dimensional self theoretical model (1967) to Harter’s (1984, 1985, 1986) development of the multidimensional stage theoretical model of self-concept, and a questionnaire to investigate the elements of children’s self-concept in different stages [11].

2.2 L2 Motivational Self System (L2MSS)

L2 motivational self system (L2MSS) is mainly composed of three components, namely “ideal L2 self”, “ought-to L2 self” and “L2 learning experience” [8]. “Ideal L2 Self” is a powerful driving force for L2 learning, including “integrative motivation” and internalized “instrumental motivation” in traditional concept which is also called “instrumentality-promotion motivation” [12]. “Ought-to L2 Self’, that is, external motivation to satisfy others or avoid possible negative results, is equal to less internalized “instrumental motivation” [12]. “L2 Learning Experience” is closely related to learning situation and learning experience, such as peers, teachers, successful experience, curriculum arrangement, etc. [12].

2.3 L2 Motivational Self System from the Perspective of Complex Dynamic Systems Theory

The key words of complex dynamic systems theory (CDST) are complex and dynamic. A system is composed of multiple parts, and each part is interconnected, resulting in the nonlinear, complex and dynamic development of the systems [12]. CDST is widely used in meteorology, economics, linguistics, etc. [11]. The research and application of CDST in the field of Second Language Acquisition (SLA) was first proposed by Larsen Freeman (1997), and then came into public view in 2002 [13, 14]. The proposal and promotion of this theory also provides the field of SLA with a new vision and perspective. The traditional research paradigm of L2 motivation is stable and linear model. There is a direct causal relationship between variables, and there is a fixed research paradigm [15]. The research paradigm of dynamic systems theory is complex, nonlinear and dynamic. The internal components of the studied system are interconnected and constantly changing, because the current research on L2MSS under CDST is challenging in all aspects. For example, what research methods can be used to measure the change mechanism of dynamic L2 motivation based on the changing elements, which scholars are still exploring. Dörnyei, Macintyre and Henry (2015) proposed the study of L2 motivation change from linear to nonlinear under CDST, and found several main characteristics of motivational change, namely change, stability and context [16, 17]. In addition, Yu Qian (2018) pointed out that there were self- organization and timescales [13]. At present, there is little research on this in China. Peng Jiane (2015) analyzed and studied the impact of the three components of L2MSS on L2 learning, and believed that among the three, learning experience had the greatest impact on effort [18].

2.4 Learning Motivation of English Majors Upgrading from Junior Colleges to Undergraduates

"Upgrading from junior colleges to undergraduates" is a form of improving academic qualifications for junior college graduates in China. There were not many studies on the learning motivation of c-u English majors. Zhang and Hong (2000) conducted a case study on the learning ability, motivation and learning achievement of these students, and believed that learning ability and learning motivation have a great correlation to learning achievement. The success of teaching should not be limited to teachers, but depend on students to a greater extent [19]. Sun's (2015) research on the learning motivation of c-u English majors mainly focused on the factors affecting the learning motivation of this group and how to affect it and concluded that the eight components affecting their learning motivation are interest, immediate achievement, learning situation, going abroad, social responsibility, individual development, media and respect need. Among them, respect need is their unique feature [20]. There is no concept matching with "upgrading from junior colleges to undergraduates" outside China.

3 Empirical Research

3.1 Research Questions

This study mainly focuses on the L2 learning motivation of c-u English majors. The main research questions are as follows:

- How does their L2 learning motivation change and develop from junior colleges to the undergraduate period? Is it stronger or weaker than before?
- How do the motivational components of L2MSS affect L2 learning motivation from the perspective of CDST?
- What are the main reasons for the influence of various components on L2 learning motivation?

3.2 Research Methods

This study mainly adopts semi-structured interview and self-narration to conduct case study. The semi-structured interview was adopted since it is more conducive to the in-depth analysis of the research problems. It not only provides the interviewees with the research direction involved in this research, so as to avoid the risk of deviation from the topic when they are interviewed, but also provides the interviewees with enough space to diverge their thinking and deeper and more comprehensive view [12]. Therefore, the semi-structured interview greatly deepens the participation of the research subjects and provides substantive help for this study. Case study was also conducted in the way of self-narration, mainly because the first author is also a c-u English major which meets the requirements of the research subject and has a deeper and authentic reflection.

3.3 Research Subjects

This study collected data by means of in-depth interview, in which the interviewer adopted the strategy of "calibration sampling", which refers to setting a certain standard for sampling, and then selecting research subjects according to the standard for case study [21]. The standards of this research subjects meet the following conditions at the same time: 1) Undergraduate students in grade 2020; 2) Upgrading from junior colleges to undergraduates; 3) English majors; 4) Grade point average (GPA) level during undergraduate period (The subjects themselves provided according to their academic grade points in the same major). The subjects of the study were six undergraduate students majoring in English upgrading from junior colleges to undergraduates in grade 2020 in three universities.

Table1. Background information of the six research subjects.

[a.] N1 in Table 1 is the first author.

Research Subjects	Age	Gender	Major in Junior Colleges	GPA Level in Universities
W1	23	female	Business English	intermediate
W2	22	female	Applied English	intermediate
N1	23	female	Business English	high
N2	22	male	Applied English	low
Z1	22	female	Business English	intermediate
Z2	22	female	Business English	intermediate

3.4 Results

English Learning Motivation During the Junior College Period

Ideal L2 Self

During junior colleges, the six students' overall motivation to approach their ideal self-image is not strong, accounting for about 30% of their English learning motivation. Take W1 as an example. During her junior college, her English learning motivation due to her ideal career accounted for about 30%. During this period, her ideal career was to become a simultaneous interpreter. She also hoped to prove her learning ability and English ability through English learning, but it only accounted for a small part of her English learning motivation during the period.

> "Part of the reason why I studied English in junior college was that I hope to become a simultaneous interpreter after graduation, which accounted for about 30% of my English learning motivation. In addition, I also think English is a subject I am good at, and I am more interested in it, which also supported me to study English in junior college. Finally, a small part of the reason was that I hope to prove my ability through learning " (W1, Friday, Feb. 25, 2022)

However, what is interesting about the interview content is that among the six research subjects, Z2 is obviously different from the other five. After entering her junior college, her goal had always been to upgrade her academic qualification. At the same time, she also had her own ideal career to become an English teacher in the future. In general, Z2's internal motivation during the junior college was sufficient, and her learning motivation was mainly composed of ideal L2 self.

"There were two main English learning motivations during the junior college period. One of them was c-u exam. As a goal of struggling, c-u examination was a clear goal in my heart, so I would spend time every day in learning English. Generally speaking, during that period, my internal learning motivation was greater than external learning motivation." (Z2, Saturday, Feb. 26, 2022).

Ought-to L2 Self

During the junior college, six students' English learning motivation was mainly produced by the social pressure of the external environment, mainly for graduation diploma, English related exams (English certificate exams; final exams) and employment. Except Z2, the other five mentioned the external pressure mainly from graduation, English related exams and employment during this period, accounting for about 60% to 70%. In addition, W2, N2 and Z1 all mentioned the pressure of peer competition. There is also a unique motivation to follow the course arrangement proposed by N1. Since Z2 was mainly driven from intrinsic motivation during this period, her ought-to L2 self motivation was hardly found

L2 Learning Experience

During the junior college, the L2 learning experience was generally less mentioned. N2 mentioned that in the high school, because of his teacher's nice personality and the good class atmosphere, this English learning motivation continued at the junior college.

> "When I was in high school, my English teacher was a humorous and active person. It was just because of him that I would be more willing to listen to his classes, so I think that teacher had a great influence on my English study. And the excellent peers around me also promoted myself to learn English to a certain extent. But these were not the main part. " (N2, Saturday, Feb. 26, 2022)

However, Z2 is more special. Her English learning motivation during the junior college period largely came from her interest in English learning. After the college entrance examination results came out, she had always planned to upgrade to undergraduate to make up for the regret of her failure in college entrance examination.

> "One of my motivation was interest, which was the best teacher, and because I like it, I spent a lot of time and energy on learning English. " "I decided to prepare for

> c-u examination after my college entrance examination results came out. " (Z2, Saturday, Feb. 26,2022)

English Learning Motivation During Preparation for C-U Exam Period

Ideal L2 Self

During preparation for c-u exam period, through the interview and the author's self narration, it can be seen that the same English learning motivation component of the six students is the ideal L2 self. One of the factors everyone has is to upgrade their academic qualification, accounting for more than 80% on average. Everyone has internalized the pressure of exam to their own motivation during this period. At this time, these students hoped to improve themselves through c-u examination, which belongs to instrumentality-promotion motivation.

> "During the exam preparation period, the first thing was to pass c-u examination, which accounted for about 80% of English learning motivation during this period. The second was to prove my ability." (W2, Saturday, Feb. 26, 2022)

Ought-to L2 Self

During preparation for c-u exam period, the six subjects generally did not show the motivation component of ought-to L2 self.

L2 Learning Experience

During preparation for c-u exam period, the L2 learning experience was not shown much among six students. Only N1 and Z2 mentioned the influencing factors related to the L2 learning experience in the hope of making up for the regret of the failure in the college entrance examination. In addition, W2 added that the support of their families and the encouragement of their classmates and teachers became her own learning motivation, and found that learning English was also an interesting thing during preparation for c-u exam period.

> "Finally, the encouragement of my family, teachers and classmates has become the driving force for me to learn English, and I gradually felt that English was very interesting during the preparation for c-u exam period, which urged me to learn English more actively." (W2, Saturday, Feb. 26, 2022)

English Learning Motivation after Entering Undergraduate Universities

Ideal L2 Self

After entering undergraduate universities, the factors affecting ideal L2 self motivation have changed greatly. Among them, all the research subjects mentioned improving their abilities. Except that W1's ideal career was still vague, the other five mentioned the positive impact of their ideal career on English learning motivation. In addition, W2, N1 and Z2 mentioned more influencing factors in other aspects.

> "After entering undergraduate period, my main motivation for English learning is to take the postgraduate entrance examination. Because the success of the c-u examination gave me great confidence, I thought whether I could go to a higher level. During the undergraduate period, I first learn my professional courses well,

> and then improve my academic qualification on this basis." (W2, Saturday, Feb. 26, 2022) "I hope to become an effective English learner during this period." (Z2, Saturday, Feb. 26, 2022)
>
> "At the same time, I prefer Western culture and hope to communicate fluently with foreigners." (W2, Saturday, Feb. 26, 2022)

Ought-to L2 Self

After entering undergraduate period, the six students were also subjected to the social pressure of the external environment to a certain extent. Among them, W1, N1, N2 and Z1 all mentioned English related exams, like English certificates (TEM-4: Test for English Majors Grade 4 and TEM-8: Test for English Majors Grade 8), as well as graduation pressure.

> "During the undergraduate period, I have the pressure of TEM-4 and TEM-8 exams, as well as the pressure of graduation." (W1, Friday, Feb. 25, 2022)
>
> "During the undergraduate period, there is a lot of pressure in acquiring the relevant English certificates, which will promote me to learn English passively. Secondly, there is the pressure of graduation." (N2, Saturday, Feb. 26, 2022)
>
> "During my undergraduate period, the external pressure is mainly the pressure of graduation, followed by the examinations of English related certificates, accounting for about 40%." (Z1, Friday, Feb. 25, 2022)

But W2 thinks that she has little pressure in these aspects during undergraduate study, and even Z2 says that she has no pressure on related English tests and graduation. At the same time, it is interesting that among the six students, except W1, the other five think that part of their English learning motivation comes from the comparison with the four-year undergraduates (students who directly enter undergraduate universities through college entrance examination). When asked whether they think their motivation is stronger or weaker than that of the four-year undergraduates, W2, N1 and Z1 think it is stronger, while W1, N2 and Z2 think it is weaker.

> "I think that compared with them, our English learning motivation is stronger, because we are more aware of the importance of academic qualifications after our junior college study and the competition of c-u exam." (N2, Saturday, Feb. 26, 2022)
>
> "I think compared with four-year undergraduates, our English learning motivation intensity is weaker than theirs, because our foundation and ability will be worse than theirs." (Z2, Saturday, Feb. 26, 2022)

At the end of the interview, W1 and N2 both felt the pressure of excellent peers around them to learn English, and N2 also felt the pressure from teachers and parents.

L2 Learning Experience

After entering undergraduate period, the motivation of six students in L2 learning experience has also changed greatly. All six agreed on the impact of teachers on them in the process of English learning.

"During the undergraduate period, I prefer the teacher's humorous way of class, such as Advanced English course, and I can get along with the teacher like a friend, which will have a positive impact on my English learning." (W1, Friday, Feb. 25, 2022)

W1, W2 and Z2 all believed that peers have a positive impact on their English learning motivation. In addition, W1, W2 and N1 all said that their successful experience of c-u gave them great confidence in English learning.

"In addition, my motivation to learn English in undergraduate period also largely stems from my successful experience in c-u examination, which is a great motivation for me to learn English in university. To be honest, because of this success, I am surer of my ability and my will becomes firmer in my mind." (N1, Saturday , Feb. 26, 2022)

N1, N2 and Z1 all said in the interview that the university curriculum had a positive impact on their English learning. In addition, both N1 and Z2 mentioned that they strengthened their English learning motivation because of their achievements during their undergraduate period.

"At the same time, my successful experience in obtaining academic scholarships during my undergraduate period also makes me more motivated to become better." (N1, Saturday, Feb. 26, 2022)

"I have achieved very good results in English speech during my undergraduate period, which will encourage me to continue to strive to achieve better results." (Z2, Saturday, Feb. 26, 2022)

In addition, W2 said high intensity learning of c-u exam preparation period established her habit of English learning.

"Now I feel that learning English has become a habit, so I continue to learn English." (W2, Saturday, Feb. 26, 2022)

Finally, the support of family also plays an important role in their English learning as Z2 said.

"I always feel that teachers play a guiding role in learning, and my parents have always been around to encourage me, which will become the driving force for me to continue learning English." (Z2, Saturday, Feb. 26, 2022)

3.5 Discussion

According to the research results and analysis, the following conclusions are drawn to answer the questions of this study.

How does their L2 learning motivation change and develop from junior colleges to the undergraduate period? Is it stronger or weaker than before?

[b.] If no accurate score is given, the data in the table shall be the average scores.

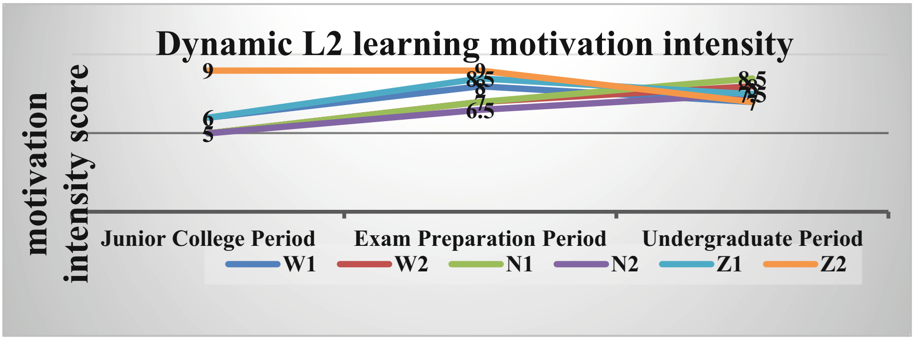

Fig. 1. Six Subjects' Scores out of Ten on the Intensity of L2 Learning Motivation During Three Periods

It can be seen from Fig. 1. That L2 learning motivation of six students in the three periods generally showed an upward trend, among which W2, N1 and N2 showed a straight-line upward trend. However, W1 and Z1 show an upward trend in the L2 learning motivation during the examination preparation period, then decrease after entering the undergraduate period, but still higher than the level in the junior college period. This result is also consistent with Chang's (2019) conclusion that once the exam is over, learning motivation will reduce or maintain. For the motivation system, this change means that the attractor disappears, and the system tends to be unstable until the next wave of attractor appears and the system tends to be stable again [16]. Z2 is special. She has maintained a high level of L2 learning motivation of 9 points out of ten before entering the undergraduate period, but it has decreased a little after entering the undergraduate period. Therefore, for those students whose motivation level is rising, we need to find a good learning strategy to maintain their motivation, and for those students whose motivation level has decreased after entering undergraduate period, we need to find the reasons in time, such as the lack of accurate goals. But on the whole, the learning motivation has improved compared with the junior college period except Z2, and it also indicates that c-u learning experience plays a positive role in students' English learning on the whole.

How do the motivational components of L2MSS affect L2 learning motivation from the perspective of CDST?

During junior college period, ought-to L2 self is the main motivation component that affects students' learning motivation, while ideal L2 self and L2 learning experience have a little influence at this stage. During c-u exam preparation period, students are mainly affected by the ideal L2 self component, not by the ought-to self component, and less affected by the L2 learning experience. However, the research found that not only positive learning experience but also some certain negative learning experience can promote English learning motivation. After entering the undergraduate period, students' L2 learning motivation is affected by three components, among which the ideal L2 self component is still dominant, followed by the L2 learning experience, and finally the ought-to L2 self. At the same time, it is found that in some cases, the ought-to L2 self should be transformed into the ideal L2 self. This conclusion is consistent with the research conclusion of Liu, et al. (2012): "Influenced by Chinese social culture, ideal self and ought-to self interact and blend with each other" [22]. At the same time, during preparation for c-u exam period, ought-to L2 self motivation disappeared. After entering the undergraduate period, it reappears, and the influencing factors are almost unchanged, except for a comparison with the four-year undergraduates.

What are the main reasons for the influence of various components on L2 learning motivation?

The factors affecting the three components of L2MSS during the junior college period are as follows:

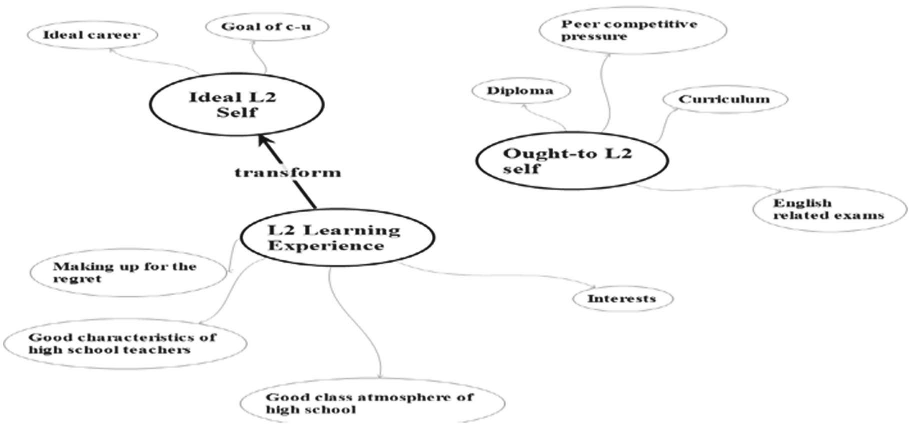

Fig. 2. Main Influencing Factors of the Three Motivation Components During the Junior College Period.

The factors affecting the three components of L2MSS during c-u exam preparation period are as follows:

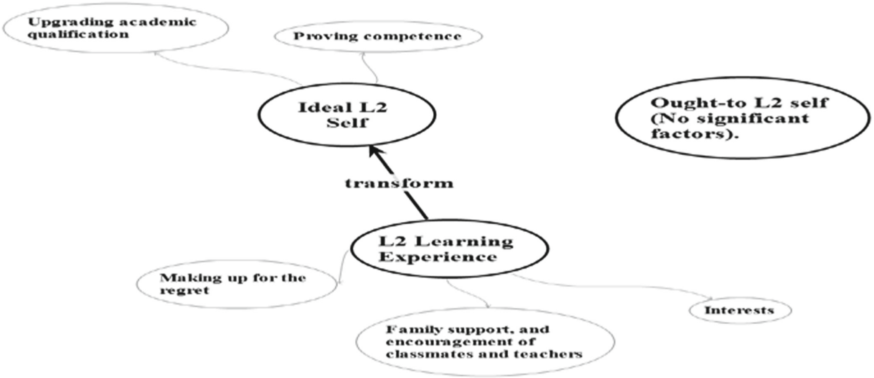

Fig. 3. Main Influencing Factors of the Three Motivation Components During C-U Exam Preparation Period

The factors affecting the three components of L2MSS during the undergraduate period are as follows:

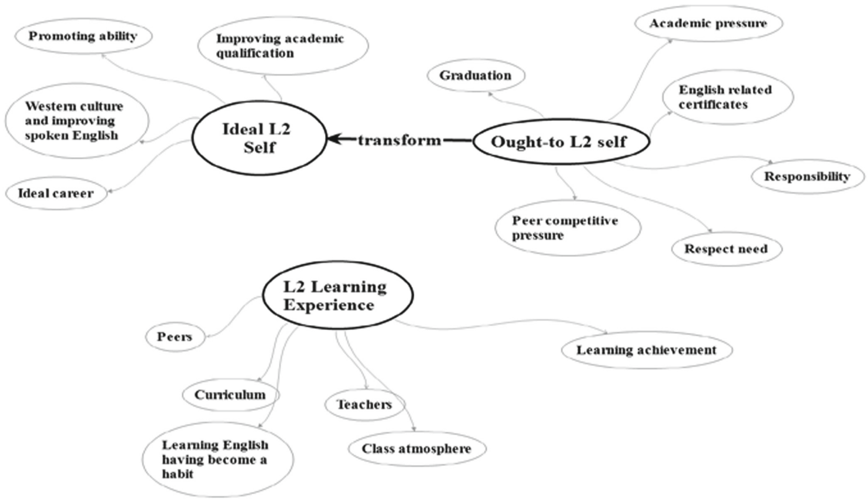

Fig. 4. Main Influencing Factors of the Three Motivation Components after Entering the Undergraduate Period

4 Implications for English Teaching and Learning

4.1 The Use of Ideal L2 Self Motivation

Establishing Correct and Clear Learning Objectives

It can be seen from research subjects whose learning objectives during junior college are not clear. As N1 said, they had the courses passively. Therefore, both teachers and parents are supposed to communicate with students in time, for especially college teachers and students lack communication [23]. In addition, the frequency of communication should be increased after encountering critical moments or events, so as they can timely understand students' current learning objectives and learning status, and give guidance.

Teaching Students According to Their Aptitudes and Giving Full Play to Students' Agency

Teachers should fully consider the situation of different students and timely adjust the teaching methods in the teaching process according to the differences in learning motivation between two types of undergraduates. And teachers should pay attention to the cultivation of students' autonomous learning strategies. Learning strategies vary from person to person, not applying a model, so students should find their most suitable learning strategies to promote English learning and improve English learning motivation.

4.2 The Use of Ought-To L2 Self Motivation

Exerting Appropriate Pressure on Students
When students' learning motivation is insufficient, teachers should find out the specific reasons through communication to timely adjust their teaching methods and help students solve the corresponding learning difficulties. However, if like subject Z2, when the students' internal learning motivation is really sufficient, there is no need to exert additional pressure, otherwise it may weaken the students' learning motivation.
Promoting Ought-to L2 Self Motivation Internalization
Ideal L2 self and ought-to L2 self will directly affect whether students are willing to invest time and energy in English learning. However, ideal L2 self motivation is more effective in stimulating students' English learning behavior [21]. Therefore, internalizing ought-to L2 self motivation into ideal L2 self in the process of English learning is more conducive to improving students' motivation to learn English.
The Use of L2 Learning Experience Motivation
Cultivating and Maintaining Students' Interests in English Learning

> Einstein once said, "interest is the best teacher." Firstly, teachers should provide students with as many learning materials as possible in the teaching process, so that students can learn English in a variety of ways, such as English songs, movies, customs, cultural differences and so on [24]. Secondly, students should learn English after class, so as to have an in-depth understanding of the contents introduced by teachers in the classroom, choose one or several aspects they are more interested in, and adhere to long-term learning.

Creating a Relaxing and Pleasant Learning Atmosphere for Students

- Harmonious Family Environment
- Professional and Fair School Environment
- Providing More Channels for Learning English from the Society under Strict Supervision

Encouraging Students to Participate in Various Professional Competitions and Activities.
According to the research results, after entering the undergraduate period, the L2 learning experience has a great impact on learning motivation of these six students, part of which is some honors or achievements they obtained during the undergraduate period. Then, encouraging students to participate in these professional competition activities can not only enhance students' professional abilities, but also strengthen students' learning confidence.

5 Conclusions

For c-u English majors, it indeed has some significance using L2MSS theory and CDST in the future research. The findings of this study include:

- The overall English learning motivation of c-u English majors is on the rise, although some also have a slight downward trend after the c-u examination.
- Supported by L2MSS theory and from the perspective of CDST, in the three periods, these students are mostly influenced by the ideal L2 self; ought-to L2 self plays a decisive role in junior college period; after entering the undergraduate period, the L2 learning experience also greatly affects students' learning motivation.
- From the perspective of CDST, L2 learning motivation is dynamic, changing all the time, so there are different primary and secondary factors affecting students' L2 learning motivation in different periods.
- C-u undergraduates will have respect need after entering the undergraduate period.
- During the junior college and c-u exam preparation period, some negative learning experiences can also have a positive effect on learning motivation.
- During the undergraduate period, the two motivational components of self-concept, namely ideal L2 self and ought-to L2 self, can be transformed.
- Ought-to L2 self appears again at the undergraduate period after it disappeared at the period of preparation for c-u exam.

Of course, this study has limitations: the research method is mainly qualitative, and the number of cases is not large enough. This study still provides some theoretical enlightenment and teaching suggestions for three different components of L2MSS. However, in L2 teaching, motivation is not the only influencing factor. Teachers and students should combine other relevant factors, learning environment and students' own characteristics to learn and master English.

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Post-editing Performance of English-Major Undergraduates in China: A Case Study of C-E Translation with Pedagogical Reflections

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Abstract. Nowadays, post-editors are in great demand in China. Therefore, this research aims to study the post-editing performance of English-major undergraduates from NingboTech University. The results indicate that: Overall, the post-editing ability of English-major undergraduates is still not sufficient for professional post-editing tasks; Their post-editing performance is related to the type of texts, and they have better performance in post-editing informative texts, while they are relatively weaker in the post-editing of expressive and vocative texts; Their post-editing quality is related to their dependence on machine translation, and the group with higher post-editing quality has a relatively lower average dependence on machine translation, but no proportional correlation is found between the two; The errors in students' post-editing versions can be mainly classified into language competence-related errors and translation competence-related errors. Based on the results, several pedagogical implications for post-editing teaching in the future are discussed.

Keywords: Machine Translation · Post-editing · Student Translators · Translation Pedagogy

1 Introduction

Nowadays, the process of internationalization is gradually deepening, and translation has become an increasingly important carrier of communication between different cultures. But the number of translators cannot meet the huge demand for translation, so machine translation emerged. However, many problems appeared while using machine systems for translation as machine-translated texts are still far from publishable quality except in some narrow domains [1]. Therefore, correction by human is necessary to make machine translation output more understandable and accurate [2]. This has led to the currently heated issue of post-editing. But the research on post-editing in China is still in its initial stage, focusing mainly on its introduction and application [3], and the teaching of machine translation and post-editing is still a weak research field [4]. Consequently, the cultivation of students for more job-oriented applications is highly necessary at the moment.

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By carrying out an empirical study on the English-major undergraduates in NingboTech University, this study will focus on English-major undergraduates' performance in post-editing in the Chinese-English language pair. On this basis, this study will analyze the current deficiencies in post-editing teaching and put forward some pedagogical implications and improvement measures.

2 Literature Review

Nowadays, in order to balance productivity and quality in translation and to give full play to the advantages of human-computer interaction, the model of machine translation plus post-editing has been widely used [5]. Due to the improvement of machine translation technology, the growing market demand for translation, and the cost of human resources, post-editing will play an increasingly important role in the language service industry and translation teaching field [3]. Therefore, the combination of machine translation and human post-editing has its significance both theoretically and practically. So far, many studies have already been done in the field of post-editing, mainly focusing on its productivity, quality, and cognitive efforts. The main results will be introduced in the following paragraphs.

Many researchers have focused on productivity gain resulting from post-editing. As concluded by Plitt and Masselot, machine translation post-editing helps translators improve their throughput by 74% on average, saving 43% of their time [6]. Robert thinks that post-editing can increase translators' productivity from an average of about 2,000 words per day to about 3,500 words per day, thus contributing to an increase of about 30,000 more words per month [7]. Guerberof conducted an experiment including eight professional translators and witnessed 13%–25% of productivity gains compared with human translation [8]. However, the experiment conducted by Garcia showed that the productivity gains in the process of post-editing were marginal [9]. Therefore, at least for the moment no general conclusion can be drawn about the productivity of post-editing compared with the traditional translation process.

In contrast, studies about the quality of post-editing present rather similar results. The number of errors in machine translation is greater than in human translation in five out of eight cases in Guerberof's experiment [8]. The study carried out by Garcia in 2010 turned out that translations produced by editing machine translations were more favored in 59% of the cases [10]. Her study in 2011 further suggested that translating by post-editing was more advantageous regardless of the difficulty of the text and the capability of participants [9]. What's more, post-edited versions are of higher clarity and accuracy [11]. In a word, post-editing can improve translation quality, although the degree and aspect of its impact vary.

Apart from productivity and quality, there are also many studies about cognitive efforts in the post-editing process. O'Brien points out that pauses can indeed indicate cognitive processing in post-editing [12]. Koglin focuses on the cognitive efforts of post-editing metaphors in newspaper texts and finds that it is lower compared with manual translation [13]. Also, research has shown that post-editing can decrease the cognitive efforts in understanding source text and producing translation [14]. Although further studies are still needed in this field, it can be tentatively concluded that post-editing can relieve the cognitive burden in the translation process.

Although much research has been done about post-editing, much research gap still exists in this field. Specifically speaking, current research in this field is mainly about the translations in the same language family, especially the Indo-European language family, with little research about language pairs in different language families. What's more, the participants in these studies are mostly professional translators or postgraduates in translation major. In addition, the vast majority of them use Google Translate in the research as machine translation system, while studies concerned with Baidu Translate, which was widely used in China, are relatively few. This research will try to fill in this research gap, and the specific method will be introduced in the next section.

3 Methodology

3.1 Research Goals

The main purpose of this study is to gain some insights into the following question: What are the performances of English-major undergraduates in post-editing tasks? The sub-questions include: 1) How do English-major undergraduates perform in post-editing tasks currently? 2) What is the impact of text types on their post-editing performances? 3) Are the post-editing performances of English-major undergraduates directly related to their dependence on machine-translated text?

3.2 Participants

The participants of this study are 95 English-major undergraduates from NingboTech University in Zhejiang, China, all of whom were enrolled in 2019. They are all native Chinese speakers, with Chinese as their first language and English as their second language. They have already taken one semester of translation theories and practice lesson in which the basic principles and methods of translation are introduced, and they have taken a business English translation course. None of them have any professional training in post-editing or any work experience as post-editors. All of their personal information and performance are only used for this study and are strictly confidential.

3.3 Material

The material of this study was selected from the 2019 Social Responsibility Report of Geely Holding Group, a famous automobile manufacturer in Zhejiang, China. As Geely is a listed company on the Hong Kong Stock Exchange, it has real needs for communications in both Chinese and English, so its social responsibility report has versions in these two languages and their quality can be guaranteed. Based on Newmark's theory of text types [15], three texts (Text A, Text B, and Text C) were selected from the whole report, which were expressive, informative, and vocative respectively. The texts were abridged and modified, with brand names removed to prevent students from searching the original text directly on the Internet. Moreover, in order to reduce the effect of the difference between text difficulty on the results, they are similar in length, containing 175, 174, and 175 words respectively. After that, the three texts were pre-translated by Baidu Translate from Chinese to English (December 2021). Then they were pasted into a Word file in a whole passage, along with the source text in Chinese. It is worth mentioning that the three paragraphs are not separate in the file and the participants are not informed of the types of each paragraph. As a matter of fact, the three texts were arranged in proper order to look like a coherent profile text of the company. This is to ensure that participants maintain the same habits and steps while post-editing the three different types of texts.

3.4 Evaluation of Translation Quality

In order to ensure the accuracy and reliability of the result, this study uses a two-dimensional evaluation method to evaluate the post-editing versions of the participants.

The first dimension is the BLEU score. It is a method of automatic translation quality evaluation proposed by IBM in 2002. The central idea of it is that the closer a machine translation is to a professional human translation, the better it is. A BLEU score ranges from 0 to 1, and it will be closer to 1 if the translation has higher quality and vice versa [16]. Due to its advantages of high speed, low cost and objectivity, BLEU has been used in translation quality assessment by many researchers [6, 17–19]. This study uses the natural language toolkit in Python to calculate the BLEU scores of each participant's post-edited version. The human translation used for reference is the official English version of the Social Responsibility Report, with some necessary modifications being made to ensure its quality. The BLEU score of every participant's translation as well as the three texts in each passage was calculated separately.

The other dimension is the marks produced by human grading. It is based on Pym's classification of errors proposed in 1992 which divides the translation errors into two basic forms: binary error and non-binary error. The former one refers to any error that is an incorrect translation, while the latter one refers to a translation which is not completely wrong, but may not be appropriate enough and should be further improved [20]. The specific grading method refers to the method adopted by Lee and Liao, which assesses students' post-editing quality in terms of sentences: 2 points will be deducted if a binary error occurs in one sentence, and 1 point will be deducted for non-binary errors. The maximum point loss would be 2 points for each sentence. As there are a total of 11 sentences in this material, the total points of the passage are 22, and every participant would get a mark ranging from 0 to 22 [21]. In order to make the evaluation more objective, the error analysis on the official website of Pigai will be referred to.

After getting the BLEU scores and the human-assessed marks, the final scores can be drawn by combining these two dimensions. To make the result easier to be analyzed, the final score adopts a 100-points system, in which the two dimensions both account for 50 points. The points of these two parts will be converted into the 50-point system and then be added together. Therefore, the participants' final scores can be got according to the following formula:

$$Final\ score = Human - assessed\ mark\ /\ Full\ mark * 50 + BLEU * 50 \quad (1)$$

In this way, the participants' post-editing quality can be evaluated from two aspects: the BLEU shows their similarity with the reference, indicating how "right" the translations are; while the human-scored marks take the errors they made into consideration, indicating how "wrong" they are. By using this two-dimensional evaluation method incorporating both machine and human, the evaluation of post-editing quality would be more objective and reasonable.

3.5 Research Procedure

After determining the participants and the material of the research, the material was distributed to the participants on the official website of Pigai (www.pigai.org), a frequently used website for English writing and translation in China. Then the students were required to use the editing function in Word to post-edit the material. Considering that English majors do not have post-editing experience and need sufficient time to complete the post-editing task, this study does not record participants' time in performing this task. Students have one week to work on this task and have to submit their translations before the deadline (January 20, 2022). After completing it, they were asked to hand in their translations through the website of Pigai in the form of attachment so that they can be downloaded in the original version for analysis. Then the quality of their translations will be evaluated. After that, in each translation, the number of unchanged words borrowed from the machine-translated text will be counted. The percentage of the unchanged words in the post-editing version will be calculated in order to look into participants' dependence on the original machine output. After that, the errors in participants' translations will be categorized and analyzed by human, and some pedagogical implications can be drawn on this basis. The results will be discussed in the following section.

4 Results and Discussion

4.1 Overall Results

A total of 95 translations were received in this study, but 2 of them were not completed according to the requirements and 3 were found to have used machine translations, which have to be excluded. Altogether 90 effective samples were collected for analysis. For

Table 1. Overall results of students' post-editing

	Machine Translation	Students' Average
Unchanged words in machine output	/	236.44
Word count	342	346.49
Percentage of unchanged words	/	68.44%
Binary errors	2	2.7111
Non-binary errors	7	4.1444
Human-assessed mark/Full mark	11/22	12.43/22
BLEU	0.6677	0.6668
Final score	58.38	61.60

each of them, the percentage of unchanged words in machine output was calculated, and the post-editing quality was evaluated by the method introduced in the previous section. Table 1 shows the overall results of the participants' post-editing versions.

The average length of the edited texts are 346.49 words, with little difference compared with the machine output. The percentage of unchanged words is 68.44% on average, indicating that around one third of the machine-translated text was edited by the participants. As for their post-editing quality, they got about 60% of the full score in all of the three indicators (BLEU, human-assessed marks, and final scores), indicating that the average quality of students' post-editing work is approximately the pass level but is far from satisfying. It has also been found that most of the BLEU scores students got are similar, mostly ranging from 0.6 and 0.7, with rather small differences. This is probably due to the fact that all their post-edited versions are based on the same machine output. What's more, the non-binary errors they made are about twice as many as the binary errors. It has to be made clear that in the evaluation process, a maximum of two points would be deducted in one sentence to avoid the influence of some extreme situations. It is noteworthy that although the human-assessed mark the final score of students' translation are higher than the machine translation, their BLEU scores are slightly lower compared with that of the machine output, which may be because that the BLEU is normally used to evaluate the quality of machine translation. In addition, students made obviously less non-binary errors than machine while the frequency of their binary errors increases. The following three sections will present a detailed analysis of the results.

4.2 Impact of Text Types on Post-editing Performance

The average BLEU, human-assessed marks, and final scores of each type of text are counted to show students' post-editing performance of different text types. The results are listed in Table 2.

Table 2. Post-editing performance of different text types

	Text A	Text B	Text C	Passage
Binary errors	0.62	0.87	1.22	2.71
Non-binary errors	2.58	0.18	1.39	4.14
BLEU	0.6040	0.6170	0.5474	0.6668
Mark/Full mark	4.18/8	4.09/6	4.17/8	12.43/22
Final score	56.31	64.93	53.41	61.60

From the results we can see that judged by all of these three indicators, students have better post-editing performance in Text B, namely informative text. While their scores in the post-editing quality of expressive and vocative texts are relatively lower. The ratio between binary and non-binary errors also differs between the three text types. The occurrence of non-binary errors in post-editing expressive text is more than four times compared with binary errors, indicating that most of their errors in this text type are not totally wrong, but still have space for improvement. As for vocative text, the frequency of these two kinds of errors is almost the same, while binary errors appear much more than non-binary errors in the post-editing of informative text. The reason for this result might be that the expressive and vocative texts focus more on the orators and readers, contributing to their diversification of translation, thus increasing the difficulty of translation and post-editing. Contrarily, informative texts focus more on facts and reality, calling for fewer translation skills.

In short, different text types do have an impact on students' post-editing performance. They have a more satisfying performance in post-editing informative text, while their performance in post-editing expressive and vocative text is relatively inferior. It is worth mentioning that as texts are diverse, not every text can be categorized into these three types and some texts may be divided into more than one types. Therefore, this conclusion may not be absolutely right in every context.

4.3 Correlation Between Students' Dependence on Machine Translation Output and Their Post-editing Quality

To study the correlation between the participants' dependence on machine-translated text and their post-editing quality, the students are divided into six groups according to three indicators of post-editing quality applied in this study: BLEU score (Group 1 and Group 2), human-assessed mark (Group 3 and Group 4) and final score (Group 5 and Group 6). The criteria for the division is the median number of each indicator. For example, the median of their marks is 12, and students whose marks are 12 and above will be divided into Group 1, and those below 12 form Group 2. For each group, their average percentage of unchanged words will be counted to show their dependence on machine output. The results are listed in Table 3.

Table 3. Groups of different post-editing quality and their dependence on machine translation

Criteria for grouping	Group	Percentage of Unchanged Words in Machine Output
BLEU	Group 1 (higher BLEU)	65.54%
	Group 2 (lower BLEU)	71.33%
Human-assessed marks	Group 3 (higher marks)	64.63%
	Group 4 (lower marks)	73.41%
Final scores	Group 5 (higher scores)	63.25%
	Group 6 (lower scores)	73.63%

As can be seen from this table, whether students are divided according to their BLEU scores, human-assessed marks, or final scores, the group with relatively better translation quality has lower dependence on machine translation. This proves that the quality of post-editing is negatively correlated with the dependence on machine translation. What's more, the average percentage of the higher quality groups (Group 1, 3, and 5) and the lower quality groups (Group 2, 4, and 6) are 64.47% and 72.79% respectively, which is higher than the results in Lee and Liao's study (58.5% for the group from the prestigious university and 66.3% for the group from a graduate institute) [21] and lower than the results in Yamada's study (69% for the pass group and 79.9% for the fail group) [22].

On the whole, it can be concluded that participants who perform better in this task make more editions in their post-editing process while the group of students with relatively inferior post-editing performance use more words from the original machine-translated text. This result corresponds to the results of the two studies mentioned above.

In order to further probe into the relation between the dependence on machine translation and post-editing, three scatter diagrams (Fig. 1, 2, and 3) are drawn using Excel, whose horizontal axes show a participants' percentage of unchanged words in the machine-translated text and the vertical axes show his or her post-editing performance. These three figures demonstrate the relation between students' dependence on machine translation and their BLEU scores, human-assessed marks, and final scores respectively.

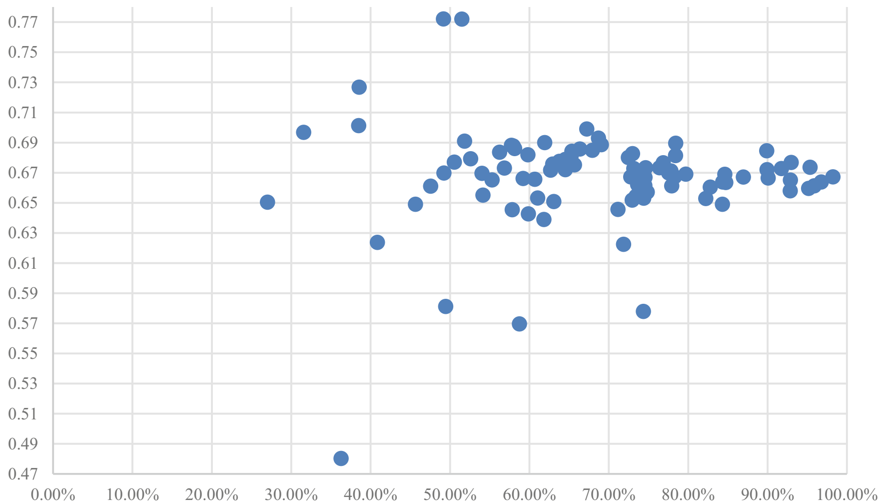

Fig. 1. Participants' percentage of unchanged words and their BLEU

From these three diagrams, we can see that participants' scores and their dependence on machine-translated texts are not proportional. A lower percentage of unchanged words in translation doesn't necessarily lead to a higher score and vice versa. Therefore, no proportional relation can be found between these two variables at least in this study. There are some possible reasons for this situation. Firstly, as we all know, translation and post-editing quality can be affected by many factors and therefore cannot be simply attributed to these two factors. In addition, in some cases in this study, the machine output is already correct without the need for modification, but the participant may mistakenly believe that the sentence has to be changed, thus making some unnecessary mistakes.

To sum up, in this study a correlation does exist between participants' dependence on the machine-translated text and their post-editing quality, but no firm conclusion can yet be drawn on this issue since no proportional relation is found between the two factors.

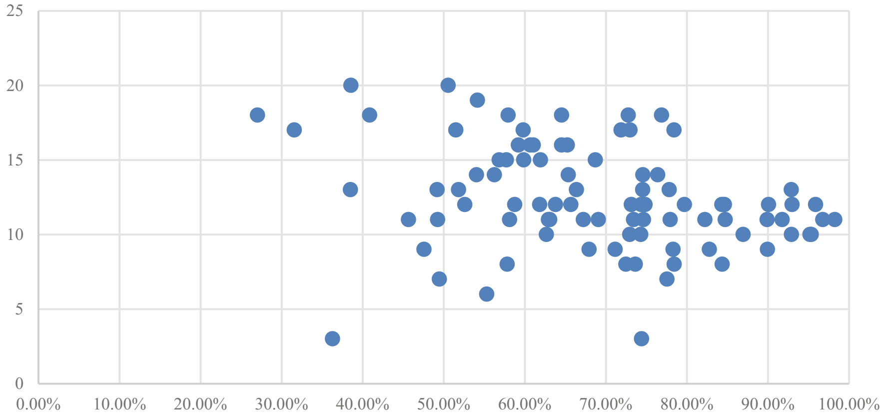

Fig. 2. Participants' percentage of unchanged words and their marks

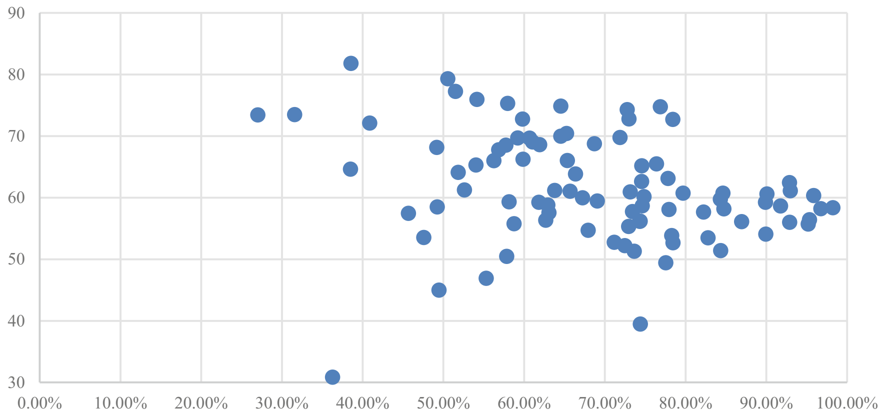

Fig. 3. Participants' percentage of unchanged words and their final score

4.4 Error Analysis

In order to get a better understanding of the errors students made in the post-editing process, the types of errors and their occurrence are analyzed. By referring to the classification of translation errors in some of the current studies [18, 23–25], this study divided the translation errors of participants into two big categories based on the root cause of the errors: language competence-related mistakes, which are caused by insufficient command of language, and translation competence-related mistakes, which are caused by inadequacy of translation capability. The former one means that the translation itself, as a piece of text, is not correct, even without considering the source text. While the latter one means that the text is not translated in the way that presents equivalent meaning and function of the original text to the readers. Based on the specific situation of the errors, this study further divided the former category into 7 small categories and the latter one into 6 small categories, with a total of 13 kinds of errors. It has to be made clear that due to the particularity of the materials and the participants, this error analysis is only for this study and is not general. The following table lists the number and percentage of each type of errors in this study (Table 4).

Table 4. Error Analysis

	Type of Error	Number	Percentage	
Language competence-related mistakes	Logical confusion	58	9.08%	52.43%
	Error of verb form	128	20.03%	
	Error of preposition	17	2.66%	
	Miscollocation of words	111	17.37%	
	Spelling mistake	3	0.47%	
	Error of sentence structure	16	2.50%	
	Ambiguity	2	0.31%	
Translation competence-related mistakes	Redundancy	32	5.01%	47.57%
	Mistranslation of proper noun	36	5.63%	
	Word-for-word translation	217	33.96%	
	Omission	12	1.88%	
	Under-translation	4	0.63%	
	Over-translation	3	0.47%	
TOTAL		639	100%	

In general, mistakes related to students' language competence are slightly more than those caused by deficiency in translation skills. In language competence-related mistakes, error of verb form accounts for the largest part, followed by miscollocation of words and logical confusions. As for translation competence-related mistakes, word-for-word translation is the most frequent one, accounting for more than one third of the total mistakes, while mistranslation of proper noun and redundancy come second and third.

It is worth mentioning that some errors made by participants in this research can be attributed to more than one reasons and some of the mistakes made by students have as much to do with their translation skills as their language abilities. Moreover, it has also been found that frequent occurrence of language competence related mistakes doesn't always lead to a large number of mistakes related to translation competence, which disagrees with the long-held view that a good command of language abilities is the premise of translation skills. It is often the case in this study that translations with many grammatical errors also have many brilliant sentences, and the specific circumstances and reasons for this are left for further research. Due to the constraint of the space, each error type will not be explained in detail.

5 Pedagogical Implications

Based on the research results, there are several pedagogical implications for improving students' post-editing abilities and teaching of post-editing in the future.

5.1 Curriculum Provision

It is advisable that the curriculum of translation talents cultivation be divided into two parts: foreign language abilities and translation competence. As is shown from the research results, the mistakes students made in post-editing are caused by the deficiency of both language and translation competence. Therefore, these two aspects of the curriculum are needed and should be taught in a more targeted way. To be more specific, in the first and second years, courses related to basic foreign language abilities should be paid more attention to. During the third and fourth years, courses including translation theories and practice, computer-aided translation, and post-editing can be incorporated to further improve their competence in translation. Of course, these two aspects should not be separated and should reinforce each other as a whole. In this way, the building of students' translation capacities can be more comprehensive and effective.

5.2 Practice of Different Text Types

This study has proved that students have different post-editing performances when encountering different types of texts. Therefore, the practice of different types of texts should be included in the post-editing teaching. When selecting materials, teachers are suggested to take expressive, informative, and vocative texts into consideration. Moreover, the practice of these three types should follow a reasonable order, namely from easy to difficult. Teachers should let students post-edit informational texts at first and gradually teach them the post-editing skills of expressive text and vocative texts. Attention should also be paid to the diversification of theme and context, helping students become more qualified for the actual demand.

5.3 Content of the Courses

In post-editing teaching, apart from the basic principles and methods of it, the introduction of the common types of machine translation errors and their corresponding solutions should also be included. If translators can understand different error types of machine translation, it will help them to locate the errors in machine translation more quickly and accurately, thus improving the efficiency of their post-editing [4]. This can be carried out by encouraging students to analyze the mistakes in machine translation themselves instead of telling them the characteristics of machine translation directly. On this basis, they are more likely to learn more quickly during their post-editing process.

5.4 Market-Orientation

This study has shown that English-major undergraduates' post-edited versions still have a rather big gap compared with the professional version. What's more, post-editing has not yet become an independent lesson for English-major students. As a result, students have little access to this important part in the language service industry. Therefore, if students can be provided with the opportunities to learn more about the career demand of post-editors and even do an internship in the language service industry, they are sure to gain a lot more.

In a word, with the rapid development of technologies and quick upgrade of translation software, translation teaching nowadays should also make adaptations in order to keep up with the time. The large demand for qualified post-editors and the imperfect post-editing performance of English-major undergraduates call for more attention and further improvements in this field. Hopefully these suggestions can be helpful to the translation and post-editing pedagogy in the future to some extent.

6 Conclusion

By conducting a case study on 95 students from NingboTech University, this research finds that: 1) Current performances of English-major undergraduates in post-editing are still not proficient enough to meet the requirements of competent post-editors; 2) Text types have an influence on English-major undergraduates' performance in post-editing. Students have more satisfactory performances in post-editing informative texts while their performances in post-editing expressive text and vocative text are relatively inferior; 3) Students' post-editing performances are related to their dependence on machine-translated text, but no proportional relation is found in this research; 4) The errors students made during the post-editing tasks can be mainly divided into language competence related errors and translation competence related skills. On this basis, some pedagogical implications are proposed concerning curriculum provision, material for teaching, content of courses and orientation.

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Assessing the AWE-Based Teacher-Assisted Feedback Model for College English Writing Teaching at the Application-Oriented University

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Abstract. The *Ministry of Education* in China promotes the full use of high-quality teaching software and teaching resources to deepen the reform of college English teaching for establishing new teaching models. Scholars generally agree that the automated writing evaluation (AWE) is feasible in English writing teaching; however, the auto-recognition of error categories needs to be improved. Previous studies have mostly focused on its application and reliability, and few have examined the AWE-based teacher-assisted feedback mechanism. We aim to examine and evaluate the feasibility and effectiveness of the mechanism by the case study of an AWE platform in China via a teaching experiment, corpus extraction from misjudged errors and its statistical analysis. The specific research questions to be addressed are: 1) What types of AWE misjudgments are actually manifested, and 2) Can the AWE-based teacher-assisted feedback model compensate for its shortcomings? It argues that under the AWE-based teacher-assisted feedback mechanism, 1) misjudgments of complex semantic recognition, complex sentence recognition and the auto-recognition of content words are likely to be commonly-shared features of the AWE platforms used in application-oriented universities in China, thus providing a general direction for operating the targeted teacher-assisted feedback mechanism; 2) the submitted times and the scoring indicates a linear correlation between the number of students' submitted times and their final scoring, and this correlation is particularly evident for individual students; when the EFL learners received the writing program under the integrated feedback mechanism, their writing and translation increased accordingly by encouraging multiple submissions, scoring refreshments, multiple feedback by means of online, offline and teacher's artificial involvement; 3) the AWE still needs to be optimized with respect to the scale of corpus data, multiple error correction algorithms, i.e., the grammatical error correction algorithms based on language models, machine translations and grammar rules.

Keywords: Automated Writing Evaluation · College English Teaching · Teacher-Assisted Feedback · Misjudged Errors · Algorithm

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https://doi.org/10.1007/978-981-99-2446-2_38

1 Introduction

In 2003, the *Ministry of Education* in China launched the program of *Teaching Quality and Teaching Reform Project of Higher Education Institutions*, which clearly proposed the use of modern information technology to reform the teaching of English at universities; in 2007, *Opinions of the Ministry of Education on Further Deepening Undergraduate Teaching Reform and Comprehensively Improving Teaching Quality* emphasized the full use of high-quality teaching software, resources and new teaching models to deepen the reform of English teaching in China. *Guide to College English Teaching at University* issued in 2020 suggested that universities should control the class size of courses such as writing class to effectively cultivate students' language output. However, in the context of the popularization of application-oriented higher education and despite the use of modern Internet technologies, the class size of college English are increasingly larger and larger, and the traditional teaching model of English writing is somewhat inoperative and inefficient [1].

Although various Automated Writing Evaluation (AWE) systems are being used in the meanwhile for teaching the first language abroad, such as *Project Essay Grade* (PEG), *Intelligent Essay Assessor* (IEA), *E-rater*, *Intellimetric*, *MY Access*, *Criterion*, *Holt Online Essay Scoring* (HOES) and *Writing Roadmap* (WR), etc., the universities in China have also tried to adopt the similar AWE to assist in teaching college English writing, e.g., *Pigai*, *iWrite*, *Bingo* and so on. Based on practical applications a large number of related research results have also appeared in China, such as the application of the AWE in college English teaching [2] and the intelligent tutoring system [3] etc. A quasi-experimental research on the basis of a t-test and a semi-structured interview analysis of 57 EFL freshmen from the Department of Applied English at a university shows that a significant difference between the experimental group and the control group in terms of writing accuracy following the adoption of AWE. i.e., students who used AWE display obvious writing enhancement in terms of writing accuracy and learner autonomy awareness [4].

Besides, The effectiveness of AWE software is a heated topic of debates among both researchers and practitioners, with advocates viewing it as an effective tool for improving students' writing, and detractors unconvinced that machines can reliably score creative written output [5]. Actually, some scholars in China examined the scoring reliability of *iWrite 2.0* based on the contrastive analysis of manual scoring and intelligent scoring [6], and conducted the comparative analysis of the two AWE platforms, *Pigai* and *iWrite 2.0*, in China [5]. In principle, scholars reach an agreement that the use of intelligent scoring systems is a trend in the implementation of foreign language writing teaching [7, 8].

Generally, AWE compares a written text to a large database of writing of the same genre, written in answer to a specific prompt or rubric, and then analyzes measurable features in a text, such as syntax, text complexity, total word count, and vocabulary range, via statistical modelling and algorithms, thus the text is given an overall score [5]. In fact, it is an efficient mechanism concluded by many teaching experiments. Unfortunately, the recognition of error categories on the AWE platforms still needs to be further improved [9].

Although the AWE systems partially emancipate teachers from overwork, the optimization of immediate feedback mechanisms and the improved efficiency of writing teaching is still constrained by the platform's intelligent misjudgment. By misjudgment, here we mean that the intelligent feedback does not necessarily reflect the objective linguistic facts of the writing text, i.e., the feedback is misidentified, biased or not identified. As can be seen, the inefficiency in intelligent judgement has a number of detrimental effects on college English writing teaching within and beyond the application-oriented universities in China.

A few scholars explored teacher-assisted feedback mechanisms based on the AWE, confirming that the teacher-assisted intervention can effectively compensate for the lack of intelligence degree [10], etc. However, few scholars paid attention to assessing the AWE-based teacher-assisted mechanism in English writing teaching. In the study we aim to examine and evaluate the feasibility and effectiveness of the mechanism by a case study of the AWE platform application in China via a teaching experiment, corpus extraction from misjudged errors and its statistical analysis.

The specific research questions to be addressed are:

1) What types of AWE misjudgments are actually manifested, and
2) Can the AWE-based teacher-assisted feedback compensate for its shortcomings?

2 Methodology

2.1 Corpus-Based Survey

A corpus-based approach is widely applied to conducting linguistics studies. The corpus data of the study, i.e., texts written online by students and intelligent evaluation texts provided by the platform, were downloaded from the *Pigai* AWE platform used as a case study. Based on the raw materials we established a corpus database in which all the intelligent evaluation texts were rejudged by researchers. Meanwhile we manually annotated the types of misjudgment by the AWE system by comparing what the platform evaluated with what the teachers did.

2.2 Samples

All the samples of misjudged errors are manually extracted from the downloaded texts which consititute the corpus database, covering narrative, applied and argumentative writing with 451 texts written by 115 students in total. For instance, the sentence *The favored policy is from today (March 1), the expiration date of this offer is March 15* was evaluated by the platform that date dignifies an appointment, but actually it dignifies *a particular day of the month or year*. This intelligent misjudgment was labelled as semantic misjudgment in the study. Another example *you will face all the joys and pains of being single, and when you get married, you will share the joys and hardships with your family members* was evaluated by the system as missing conjunction; however, it is accurate enough, thus the intelligent misjudgment was labelled as misjudgment of missing conjunctions. Finally, 1145 samples of misjudgment were found from the corpus database with 29 different types of annotations.

2.3 Statistic Analysis

1) The agglomerative clustering analysis was used by drawing a clustering dendroram for clarifying the types of misjudged errors, 2) a correlation analysis was employed to draw a scatterplot of writing performance & submitted times, exploring the correlations between the scoring and submitted times under the mechanism combined by the AWE and teacher-assisted feedback, and 3) the independent sample test was conducted to examine students' writing performance on CET4 after the teaching experiment with the combination of the AWE feedback and the teacher-assisted feedback, aiming at a visualized statistical analysis.

2.4 Teaching Experiment

In order to evaluate the effectiveness of the AWE-based teacher-assisted feedback, a teaching experiment was designed to see whether or not the teacher's assistance could compensate for the shortcomings of the AWE system. The experimental subjects were three classes in an application-oriented university in Ningbo, China, with 42, 40 and 42 students respectively in their classes; the control group was the other parallel classes at the university. The experiment lasted for nearly two semesters. A multiple feedback model combining the AWE with teacher-assisted feedback online and offline was implemented in the experimental group. While in the control group only the *Pigai* AWE system was applied. Teachers used the AWE system to extract errors from sentences, collected cases of lexical misjudgments, collocation misjudgments and out-of-context misjudgments, etc. and set up offline correction exercises and targeted lectures to improve students' language skills and enhance text contents based on online extraction of misjudged texts and offline explanations of text relevance, as shown in Fig. 1.

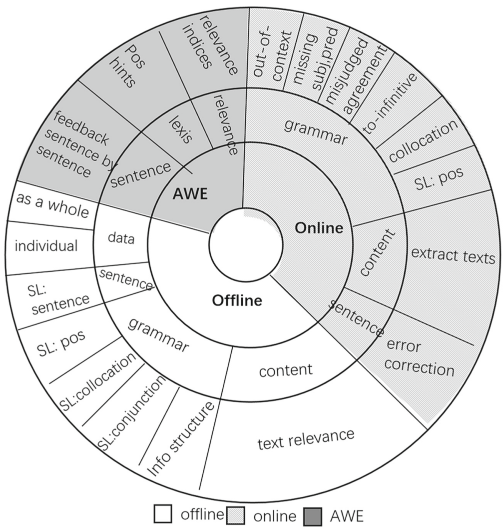

Fig. 1. Diagram of Online and Offline AWE-Based Teacher-Assisted Feedback (SL = special lectures).

3 Results

To assess the efficiency of the AWE-based teacher-assisted feedback model, we conducted the agglomerative clustering analysis of misjudged errors, the correlation analysis between the submitted times and scoring under the combined feedback mechanism, and the independent sample test of students' writing performance on *College English Test Band 4* (CET4) after the completion of the experiment in the context of the AWE-based teacher-assisted feedback.

3.1 Agglomerative Clustering Analysis of Misjudged Errors

Based on the frequency of the types of misjudgments, we conducted the agglomerative clustering analysis with Euclidean distance and Ward.D2 method (R 4.1.2). The values of the correlation coefficient produced is 0.823, showing that the clustering can well reflect the relationship under discussion. The clustering results are shown in Fig. 2.

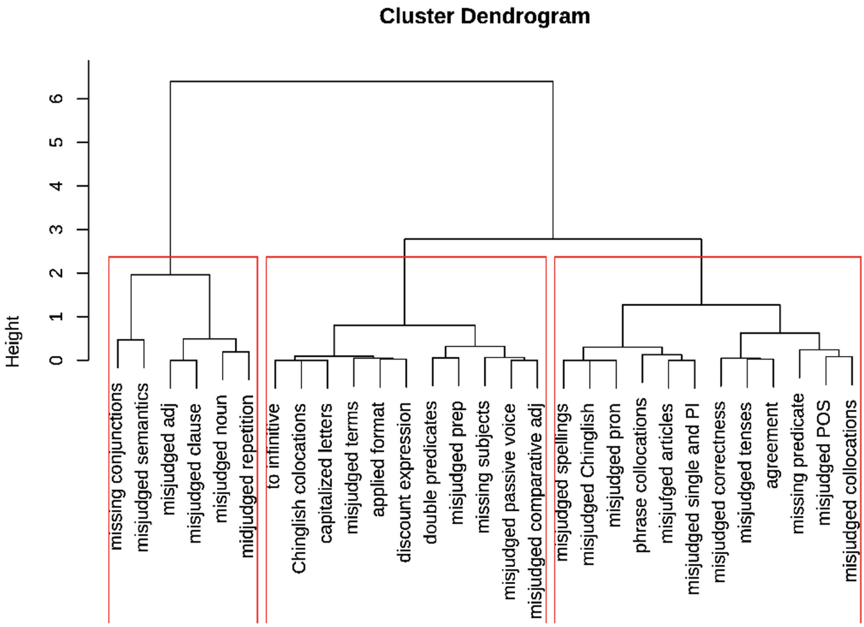

Fig. 2. Cluster Dendrogram of the Misjudged Errors.

The bottom half of the graph shows the clustering categories, and the vertical axis implies the relative distances between categories. As can be seen from Fig. 2, the types of misjudgments can be divided into three categories. The first one covers missing conjunctions (10.39%), semantic misjudgments (11.88%), misjudged adjectives (6.81%), misjudged clauses (6.81%), misjudged nouns (7.60%), and misjudged repetitions (8.21%) with high frequencies and proportions. Based on the observations, it can be found that most of the series of misjudgments are sentence-related, and the frequency of misjudgments basically show a positive correlation with the complexity of the sentences written by students.

Moreover, the second and the third category can be grouped into one major category. To be specific, the types of misjudgments in the second category include to-infinitive (0.35%), Chinglish collocation (0.35%), misjudged capitalized letters (0.35%), misjudged terms of toponyms (0.09%), misjudged applied format (0.26%), individual expression (e.g. *discount*, 0.35%), misjudged double predicates (0.87%), misjudged prepositions (1.05%), misjudged missing subject (1.48%), misjudged passive voice (1.66%), misjudged comparative adjectives (1.66%), etc. Meanwhile, the third category covers misjudged spelling (2.79%), misjudged Chinglish (2.79%), misjudged pronouns (2.79%), misjudged phrase collocations (2.01%), misjudged articles (2.36%), misjudged single and plural (2.36%), misjudged verb (3.49%), misjudged tense (3.58%), subject-predicate agreement (3.67%), missing predicate (5.15%), misjudged POS (4.63%), misjudged verb collocation (4.37%), etc. It can be found that this major category (both the second and the third categories) deals mainly with singular-plural nouns, subject absence, correspondent articles and comparative or supreme adjectives as well as the identification of content words and their semantic clustering, including verbs, nouns and adjectives represented by verb conjugation, tense change, singular-plural change, grammatical transitivity of verbs, transitive or intransitive collocations and prepositions.

The findings in line with what have been found by previous scholars from other AWE platforms provide new evidences that the AWE system or platform is inefficient in judging conjunctives in the relative clauses, lexical verb class, etc. [7], and more frequently fails in judging content words, content errors [3], and accurately assessing the intrinsic quality of the text (complexity of sentence structure, intrinsic logical connections, etc.) [2]. It can be seen that misjudgment of complex semantic recognition, complex sentence recognition and the recognition of content words are likely to be very common in various AWE platforms, thus providing a general direction for optimizing the targeted teacher-assisted feedback model.

3.2 Correlation Analysis of the Submitted Times and Scoring Under the Mechanism Combined the AWE with the Teacher-Assisted Feedback

We constructed a scatter plot and trend line of the correlation between the submitted times and students' scoring by using the number of submitted times as the horizontal axis and the scoring as the vertical axis, as shown in Fig. 3. The linear regression equation is $y = 0.0744x + 80.945$, with $a = 0.0744 < 1$, $b = 80.945 > 0$ and $R^2 = 0.0578$, indicating a linear correlation between the number of students' submitted times and their final scoring, and this correlation is particularly evident in 5.78% individual students.

3.3 Students' Writing Performance on the Standardized CET4 After the Completion of the AWE-Based Teacher-Assisted Feedback Experiment

To assess the students' writing performance on standardized CET4 after finishing the AWE-based teacher-assisted feedback experiment, data on scoring of the CET4 dated on Dec. 18, 2021 were selected for comparing the performance of the experimental

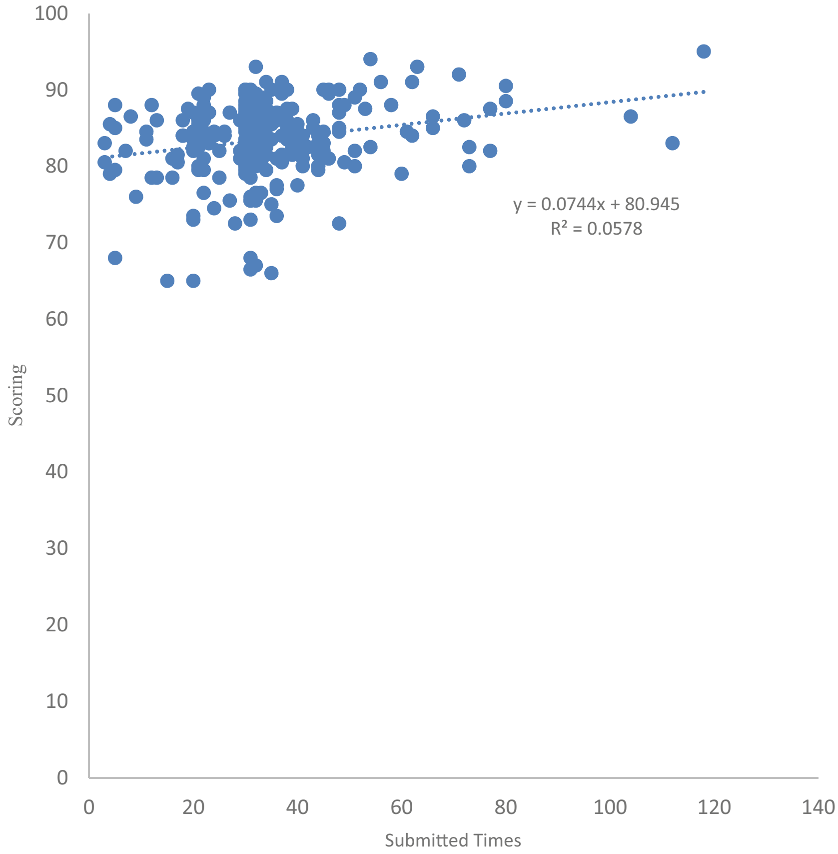

Fig. 3. Scatterplot of Writing Performance and Submitted Times.

group with that of the control group of other parallel classes across the university. It is noted that the report of CET4 scoring contains three main modules: listening, reading, translation & Writing, so we conducted the statistical analysis of the three modules as shown in Table 1.

An independent-samples t-test was conducted to compare the total scores of translation & writing in CET4 of the experimental group and those of the left classes at the university. There is a significant difference in the scores for the experimental group ($M = 145.1, SD = 14.95$) and other students ($M = 139.97, SD = 16.34$); $t\,(1047) = -2.99$, $p = .003$. The results suggest that the integrated AWE-based teacher-assisted feedback in college English writing teaching really have a positive effect upon the participants' language proficiency. Specifically, the results proves that when the EFL learners received the writing program under the integrated feedback mechanism, their scoring of writing & translation would probably increase accordingly.

Table 1. Independent Sample t-Test.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig	t	df	Sig (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the difference	
									Lower	Upper
Total	Equal variances assumed	0.007	0.931	-2.348	1047	0.019	-14.419	6.142	-26.471	-2.367
	Equal variances not assumed			-2.366	118.323	0.02	-14.419	6.093	-26.485	-2.353
Listening	Equal variances assumed	1.707	0.192	-2.14	1047	0.033	-7.33	3.426	-14.052	-0.607
	Equal variances not assumed			-1.959	113.677	0.053	-7.33	3.742	-14.743	0.083
Reading	Equal variances assumed	0.393	0.531	-0.479	1047	0.632	-1.315	2.744	-6.699	4.069
	Equal variances not assumed			-0.479	117.915	0.633	-1.315	2.743	-6.746	4.117
Translation & Writing	Equal variances assumed	0.062	0.803	-2.991	1047	0.003	-5.147	1.721	-8.523	-1.771
	Equal variances not assumed			-3.215	122.148	0.002	-5.147	1.601	-8.316	-1.978

4 Conclusions

The AWE-based teacher-assisted feedback mechanism needs to be applied owning to the AWE misjudgment and the actual deficiencies in cultivating students' writing skills for the possible targeted solutions, e.g., to conduct special thematic lectures, online and offline discussions in groups or not, and to extract incorrect words, sentences and discourse analysis for setting up correction exercises for students by a diversified feedback mechanisms integrated with online, offline and the AWE platform.

Evidences show that the teacher-assisted feedback could possibly be effective in improving students' writing skills by encouraging multiple submissions, scoring refreshments, multiple feedback by means of online and offline AWE-based teacher-assisted mechanism. More importantly, the integrated mechanism deserves to be widely publicized at the application-oriented universities in China.

However, the AWE platforms including but not limited to *Pigai* still need to be improved, and the annotated essay scoring and error correction mechanism of the platforms need to be optimized as well. In general, mistakes or errors made by the Chinese students are not always much the same as that made by the overseas English native speaking students, therefore, the corpus of Chinese students' writing mistakes or errors calls for an efficient integration of annotated texts to increase the coverage of language mistakes or errors for the AWE deep learning. Besides, multiple error correction algorithms also need to be superimposed. For instance, the grammatical error correction based on language models, machine translations and grammatic rules call for further optimization. Undoubtedly, it is anticipating to integrate the RNN-based Neuromachine translation, the CNN-based counterpart with the transformer-based counterpart for the AWE system in the future, but still a long way to go with the development of AI technologies.

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Research and Practice of Mixed Teaching Mode in Computer Network Course Based on SPOC

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Abstract. With the popularity of mobile Internet and the growing maturity of emerging technologies such as big data and cloud computing, the research on online and offline mixed teaching mode based on SPOC has become a new focus and difficulty in the course reform of college. Taking the computer network course as the starting point, this paper explores and practices the online and offline mixed teaching mode. After the specific implementation of the three important stages of guiding students' autonomous learning before class, centralized discussion in class and review and consolidation after class, and analyzes the practical effect, it is concluded that the implementation of the online and offline mixed teaching mode can effectively solve the problems existing in the traditional classroom teaching and enhance the high-level, innovation and challenge of the course, It has a good effect to improve the achievement of curriculum teaching objectives and students' learning satisfaction.

Keywords: SPOC · Ubiquitous Learning Environment · Mixed Teaching Mode · Online and Offline Mixed Teaching Mode

1 Introduction

The 5G mobile communication technology extends the high-speed wireless network to people's daily work and learning space, making the cross media real-time interactive ubiquitous learning environment possible. The growing maturity of big data, cloud computing, blockchain and other technologies has made the "Internet + education" model more perfect. MOOC (massive open online course), as a representative product of the deep integration of Internet and education, has attracted much attention. In its application process, some teaching modes that are easier to implement in Colleges have been derived due to the difference of application conditions, especially the mixed teaching mode based on SPOC, which is favored by college teachers [1, 2].

SPOC (small private online course) refers to a small-scale restricted online course, which is a restricted course open to a small number of applicants who meet the course access conditions [3]. In other words, the teaching implementation based on SPOC refers to the application of online teaching resources to the curriculum teaching of small-scale groups. It refers to the deep integration of online teaching in the process of classroom

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teaching implementation, which provides sufficient resources for the implementation of online and offline mixed teaching. The document issued by China's Ministry of education emphasizes that college across the country should systematically sort out all courses and teaching contents, eliminate unqualified courses, and strive to promote the construction of top-notch courses such as online, and online and offline mixed course [4]. This is also the first time that China has incorporated first-class courses into the national official document, which defines the relevant contents on the construction of first-class courses and points out the direction for Chinese colleges to promote the reform of online and offline mixed teaching mode. Then, the construction of online and offline mixed first-class courses has become the focus and difficulty of curriculum reform in College. Computer network course is one of the core compulsory courses of computer science and technology. The mixed teaching of this course plays an exemplary role in the innovation of teaching mode of other core courses [5].

2 Common Forms of Mixed Teaching Mode

2.1 MOOC+Classroom Teaching

As a new teaching mode, the mixed classroom teaching mode has received extensive attention from scholars at home and abroad in recent years. The rise of MOOC provides new ideas and directions for the mixed classroom teaching model.

Fox (2013) believes that the combination of MOOC and traditional classroom teaching can help achieve optimal teaching results, so he proposed SPOC [6]. He Bin and Cao Yang (2015) believe that SPOC is an inheritance, improvement, and transcendence of MOOC. Through the design and utilization of high-quality MOOCs resources, it achieves the restructuring of university teaching processes, promotes mixed teaching and participatory learning, and greatly improves the quality and effectiveness of teaching and learning [7]. Xu Xiaofeng et al. (2016) took the "General Physics" course of Tongji University as an example, analyzed the key factors affecting teaching effectiveness from three aspects: teachers, students, and the environment, and found that the use of SPOC mode can have a positive impact on learning performance and students' emotional attitudes [8].

2.2 APP+Classroom Teaching

With the emergence of intelligent mobile terminals, educational APP has developed rapidly as a new type of mobile learning resource. Currently, there are many educational APPs that have been applied to classroom teaching in universities, such as Google Classroom and Cloud Classroom. The education app has functions such as teachers assigning homework, conducting tests, and students submitting homework; Teachers can obtain data on each student's learning process at any time, statistically analyze their learning situation, and timely adjust teaching strategies to improve teaching; At the same time, the portability and simple interactivity of educational APP enhance the communication and interaction between teachers and students.

2.3 WeChat+Classroom Teaching

In recent years, WeChat has been widely used in college education and teaching due to its strong interactivity and stickiness. WeChat based teaching platforms have emerged in an endless stream, such as WeChat teaching assistants. The use of these teaching platforms has effectively made up for the limitations of traditional classroom teaching models in terms of time and space, providing new platforms and beneficial supplements for traditional classroom teaching. WeChat teaching assistants use WeChat as a carrier, consisting of a Web terminal and a WeChat terminal. Teachers create and manage classes on the Web terminal, and students participate in teacher classroom interactions through WeChat. At present, the main functions of micro teaching assistant support include: classroom management: creating a classroom, setting a time limit for classroom questions, setting up teaching assistants, setting up course team members, etc. Classroom interaction: including classroom testing, check-in, and free discussion. Problem setting management: support blank filling questions, multiple choice questions, reading questions, etc. Question answering management: You can view and export student scores, delete students, or lock classes. Question bank management: Support the sharing of questions in different classes.

The hybrid classroom teaching model based on "micro teaching assistants" has changed the interaction, control, and evaluation processes in traditional classroom teaching processes in an informational manner. Through efficient information-based interactive means, teachers' sense of control and rhythm in the classroom teaching process has been enhanced, students' sense of presence and participation in the classroom has been stimulated, and the exploration and practice of "formative" evaluation has been promoted.

2.4 Flipped Classroom Teaching

Flipped classroom teaching is a new teaching mode widely used in recent years. In traditional classroom teaching, teachers must unify their progress and cannot take into account each student. In flipped classroom teaching, students can repeatedly watch teaching videos and bring questions into the classroom before class. Teachers can explain students' questions in a targeted manner, and students can also develop full interaction and communication. In this teaching mode, it can not only play a leading role of teachers, but also reflect the dominant position of students in the classroom. Flipped classroom teaching not only improves classroom efficiency, but also reduces the learning burden of students, truly realizing personalized teaching with students as the main body.

3 The Summary of Mixed Teaching Mode

3.1 Connotation

Online and offline mixed teaching is the use of information technology, relying on the network platform, giving full play to the advantages of online classroom and traditional classroom teaching, re mining, integration and application of rich teaching resources, and extending the classroom to the network virtual space, that is, on the basis of traditional classroom teaching, combined with the teaching resources of the network teaching platform and using advanced teaching tools for network teaching, It is a new teaching method to realize the complementary advantages of online and offline teaching, complete the deep integration of traditional offline classroom teaching and online teaching, and then improve teaching efficiency and teaching effect [6]. It should be made clear that online and offline mixed teaching is not based on MOOC and SPOC mixed teaching or flipped classroom. Online teaching has the same status as offline teaching, rather than taking the form of information-based learning resources such as micro video as the basis or supplement of offline teaching; Secondly, online and offline mixed teaching is not a double teacher classroom. Online education and offline teaching are not carried out in the same time and space, and should have clear and focused teaching and training objectives; Finally, in online and offline mixed teaching, online and offline teaching should be deeply connected, not simply the relationship between "last class" and "next class". After clarifying the above points, online and offline mixed teaching refers to a teaching mode in which online and offline teachers adopt a collaborative way to effectively reflect their respective advantages of online and offline teaching, achieve online and offline teaching goals with different focuses, and implement them in different time and space [7].

3.2 Characteristic

First, different teachers in different time and space rely on online teaching platforms and offline teaching environment to carry out teaching. This is the fundamental form of online and offline mixed teaching, and it is also the basic guarantee to fully reflect the respective advantages of online teaching and offline teaching. Especially for students with general learning attitude and low learning enthusiasm, compared with mixed teaching based on MOOC and SPOC, online teaching with teachers in online and offline mixed teaching is an important condition to ensure the quality of online learning [8]. Second, online and offline teaching objectives have their own emphasis. The difference of teaching objectives is an important reflection of the respective advantages of online teaching and offline teaching in teaching. Online teaching has a better effect on knowledge and skills, and is relatively effective in knowing, understanding and using in terms of cognitive level; Offline teaching can better promote the all-round development of students. In terms of cognitive level, it is relatively effective for analysis, evaluation and creation. Differentiated teaching content and teaching objectives can maximize the unique advantages of online and offline mixed teaching. Third, online and offline teaching are deeply connected. The connection between the two is mainly reflected in two aspects: teacher cooperation and educational data sharing. Specifically, online and offline teachers complete lesson preparation based on the unique advantages of online and offline teaching, so as to realize the complementarity of online and offline teaching content and teaching objectives; The informatization and intelligence of online teaching make it naturally convenient for the collection of educational data, and intelligent data analysis and diagnosis are run through the online and offline teaching process [9].

3.3 Structure

The online and offline mixed teaching mode is mainly reflected in the following two aspects: on the one hand, under the traditional classroom teaching mode, teachers usually assign preview tasks, which are usually lack of guidance, and even many students' Preview focus is very low related to classroom teaching. However, in the online online online and offline mixed teaching mode, the content of pre-class autonomous learning is the key knowledge points video resources and learning materials carefully prepared by teachers, which are closely related to the key and difficult points of the course [10]. Through the online platform, students can carry out orderly learning according to the plan, and can communicate and discuss with teachers in time after encountering learning difficulties. The goal of pre-class autonomous learning is more clear, It has laid a solid foundation for offline classroom teaching. On the other hand, students have completed the important knowledge points of this course under the guidance of teachers before class. Teachers can adjust the teaching content in combination with students' learning results, especially for the implementation of flipped classroom in offline teaching of key and difficult knowledge, and carry out in-depth discussion with students. After class homework can be arranged in the teaching platform to collect and evaluate students' learning effects more conveniently and improve the pertinence of teachers' guidance, Promote students' understanding and application of knowledge [11].

4 Design of Mixed Teaching Mode

For the online and offline mixed teaching mode, combined with the teaching process, it can be divided into five stages, mainly including students' Online Autonomous Learning, teachers' classroom explanation, teachers' and students' classroom communication, interactive teaching situation simulation training, learning achievement report and homework completion evaluation. According to the teaching time, it can be divided into three stages: before class, in class and after class. In this regard, this paper carries out the practice of online and offline mixed teaching mode for computer network course, mainly

Table 1. Mixed teaching mode design.

Role	Stage		
	pre-class	in-class	after-class
Teacher	Teaching design, resource production, online communication	Classroom instruction, answer questions, discussion design, personalized counseling	Knowledge map, teaching design, teaching reflection, learning evaluation
Student	Pre-class learning, online questioning, unit testing, interactive communication	Ask questions, group discussion, classroom practice	Homework, knowledge review, knowledge development, teacher-student communication, teaching evaluation

from three stages: Students study independently before class, discuss intensively in class, and review and consolidate after class. The design of each teaching link of the course is shown in Table 1.

4.1 Autonomous Learning Before Class

Before the class starts, teachers' main task is to formulate the overall teaching plan of computer network course, provide students' learning schedule, and further clarify the autonomous learning tasks and learning requirements. In the stage of students' autonomous learning before class, the teacher team mainly uploads the learning resources of important knowledge points on the school network platform in advance, including teaching videos, simulation animation, teaching courseware, exercises, simulation experiments and other learning resources, and the learning completed by students within the time specified by the teacher. In the process of arranging learning tasks, it is necessary to combine students' actual learning situation and learning ability to enable students to complete the learning content matching their ability. Teachers should focus on two issues: first, the depth and breadth of students' learning in the process of autonomous learning before class; Second, whether students have the ability of self-evaluation before and after class. Based on the perspective of teachers, the autonomous learning stage before computer network class requires students not only to form a preliminary cognition and understanding of the knowledge learned in classroom teaching, but also to complete chapter exercises matching the knowledge points, so as to accurately grasp the effect of students' autonomous learning, form students' autonomous learning files and determine the content to be discussed in class. Based on the perspective of students, the process of autonomous learning before class is self-learning, sorting out notes, discussing with students, verifying with their own knowledge, forming doubt records, and participating in centralized discussion with problems in class. The effect of students' autonomous learning at this stage will have a direct impact on the practical effect of mixed teaching mode. Therefore, in the pre class learning stage, teachers should pay attention to providing students with diversified learning resources and materials. The computer network course teaching team has not only recorded more than 300 min of teaching videos and supporting chapter exercises, but also introduced two national first-class course teaching resources, so that students can obtain extensive knowledge in various ways in combination with their own learning needs, learning interests and learning habits, so as to enhance students' interest and effect of autonomous learning before class.

4.2 Centralized Discussion in Class

During the implementation of classroom teaching, face-to-face communication between teachers and students and group discussion are the key links in the practice of online and offline mixed teaching mode, so as to help students solve the doubts and puzzles of autonomous learning and realize the internalization of students' knowledge. The application of modern information technology has laid a solid foundation for the reform of mixed teaching mode based on SPOC, so teachers and students must clarify two key problems in this teaching stage: one is how students should learn in the context of mixed teaching mode, and the other is how teachers should teach in the context of mixed teaching mode. The main tasks of students include: summarizing the questions and puzzles encountered in autonomous learning before class, reasonably expressing them in classroom discussion, and confirming information through communication with teachers and students to realize the understanding and deepening of knowledge; Students should actively participate in offline classroom teaching activities, actively complete the discussion contents assigned by teachers, think about problems with innovative thinking, and communicate and discuss with students in time. The main tasks of teachers: scientifically and reasonably allocate the limited classroom time, timely give advice and help when students encounter learning difficulties, and guide students in the correct learning direction. In addition, in the process of students completing classroom practice tasks, teachers should timely find students' error prone points, summarize them, and provide centralized guidance in the classroom, so as to help students master knowledge. In the process of centralized explanation in computer network class, the main processes of students' knowledge internalization include: sharing notes and learning difficulties in self preview in class, discussing and communicating problems and difficulties, and finally explaining and summarizing knowledge by teachers, and completing knowledge internalization in the joint comment and summary of teachers and students. In this process, teachers will closely observe whether students actively participate in classroom teaching activities, enhance students' problem awareness through discussion and communication, and promote students to improve their comprehensive ability, innovative thinking and problem-solving ability in the process of raising and solving problems. In a word, in the process of practicing the online and offline mixed teaching mode, we should strengthen the student-centered teaching concept, pay attention to the innovation of teaching methods, improve the complexity and challenge of discussion contents, constantly stimulate students' creativity, focus on the improvement of ability, and effectively cultivate students' high-level ability through teaching design.

4.3 Review and Consolidation After Class

The consolidation of students' review after class can achieve a deep understanding of the learning content. Students mainly combine their own learning needs and learning progress, repeatedly watch teaching videos and problem-solving steps, actively participate in the discussion and communication activities between teachers and students, timely complete the homework assigned by teachers, check and make up for deficiencies in knowledge, and further solidify and apply the knowledge they have mastered. After class review and consolidation is a beneficial extension of offline classroom teaching, which can be divided into two links: homework and evaluation. Job design is a crucial link. In the process of homework design and arrangement after class, we should pay attention to the interest, applicability and challenge of various exercises, ensure that the knowledge involved in homework is related to students' knowledge system, truly stimulate students' learning motivation, and build a bridge of communication and blending between old and new knowledge. In the process of homework design and arrangement of computer network course, teachers mainly pay attention to the following problems: first, pay attention to the typicality of the topic, which can reflect the integration of subject knowledge and the common problems of students in the first two stages; Second, pay attention to the openness and practicality of topic selection. Students can use diversified means and methods to solve complex problems, so that students can get effective training and improve their practical ability in the process of completing their homework; Third, after-school homework should be stratified, combined with students' learning foundation and self-study ability, and designed from multiple angles to adapt to the knowledge reserve of students at different levels, so as to truly stimulate the learning enthusiasm and enthusiasm of students at different levels and promote the effective achievement of teaching objectives. The network teaching platform with rich functions provides a good evaluation means for the homework submitted by students. After uploading the homework, students can automatically obtain the score, check the answers and problem-solving process in time, and can be included in the wrong question set with one click. The function of automatic homework correction not only greatly improves the efficiency of teachers' homework correction, but also gives teachers more time to design hierarchical homework, pays attention to students with poor learning foundation and insufficient self-study ability, and promotes students at different levels to obtain personalized guidance. This platform also adds a teacher-student evaluation link, which can not only enable students to evaluate independently, but also obtain the evaluation between teachers and students. The feedback information is real-time. Teachers and students can obtain a good sense of harvest and identity, constantly find their own shortcomings and problems in the process of "teaching" and "learning", so as to improve the teaching effect and learning effect, and constantly promote the continuous improvement of online and offline mixed teaching mode.

5 Application Effect Analysis of Mixed Teaching Mode

The course teaching team designed a mixed teaching quality satisfaction questionnaire to analyze the application effect of mixed teaching mode in computer network courses and student satisfaction. For computer majors of different grades, 342 questionnaires were distributed, 336 questionnaires were returned, with a recovery rate of 98.25%, mainly from the network teaching platform, online teaching resources, online interaction, favorite teaching resources, teaching methods, Learning effect and other six aspects of data collection and analysis.

The network teaching platform and smart classroom independently developed by the school provide a strong guarantee for the practice of the mixed teaching mode of the course, and Chao Xing company provides technical support for the smooth implementation of the course. Figure 1 shows that 95.24% of the students in the class like to use the Chao Xing company platform for all-round learning activities, of which 79.17% are very satisfied with the humanized operation method, and only 4.76% of the students said that the effect of using the online teaching platform is not satisfactory. From the above data, it can be concluded that most students can adapt to learning through online teaching platforms.

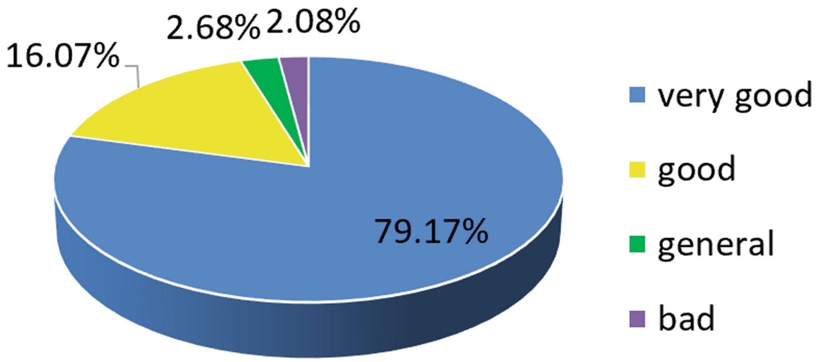

Fig. 1. Students' satisfaction with the network teaching platform.

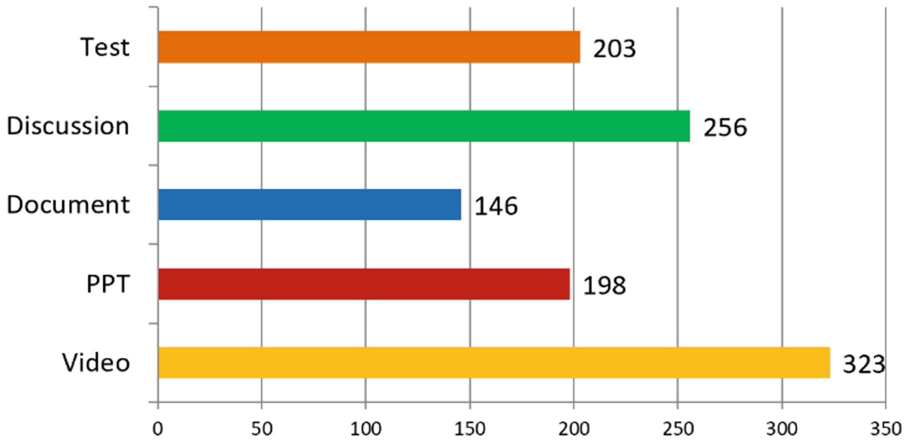

Fig. 2. Students' satisfaction with the network teaching platform.

Figure 2 shows that among the 336 students, the vast majority of students are very fond of teaching videos, and most of them also like teaching resources such as seminars, tests and teaching manuscripts. They think that teaching videos are more intuitive and visual, which is conducive to the understanding of key and difficult knowledge, and can also be repeated over time. However, for pure text learning materials, only 146 students chose them. This conclusion also reflects the learning habits and characteristics of contemporary college students.

Students' evaluation of mixed teaching is very critical. The questionnaire survey shows that 93.15% of students feel that online teaching has improved students' efficiency and effectiveness, which shows that students have a high degree of recognition of this learning model. Only 2.68% of the students chose to not adapt to the mixed teaching mode, which is mainly reflected in the inability to restrict themselves to complete the learning tasks on time, and the learning effect and progress did not meet expectations. As shown in Fig. 3.

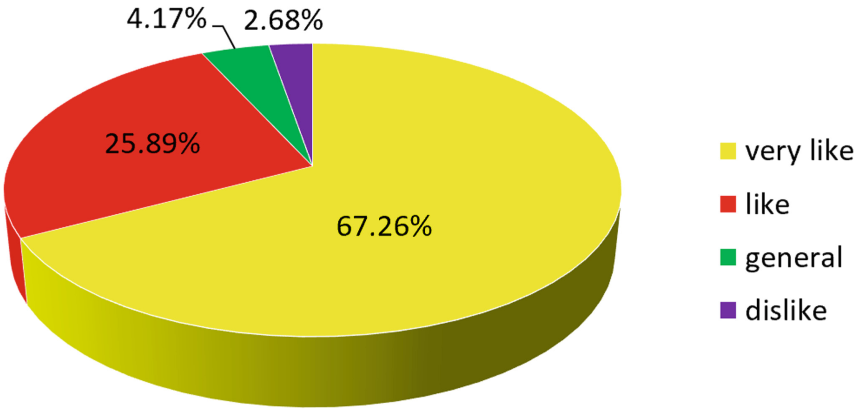

Fig. 3. Students' satisfaction with mixed teaching mode.

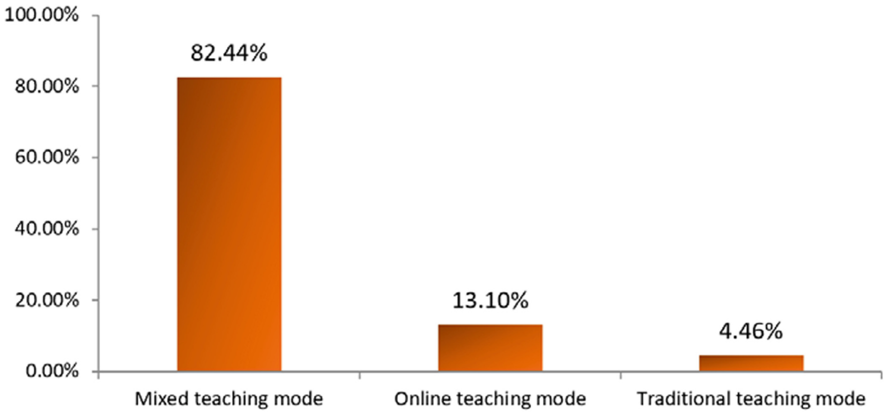

Fig. 4. The comparison of students' popularity for three teaching modes.

The last picture is the comparison of satisfaction between mixed teaching, online teaching and traditional teaching mode. From Fig. 4, it can be seen that 82.44% of students voted for mixed teaching mode, which they think is more suitable for their own learning habits, while only 4.46% of students choose traditional teacher teaching mode, which is basically the same as the proportion who do not like mixed teaching mode.

6 Conclusions

In order to improve the teaching effect of computer network courses, it is imperative to fully tap high-quality network resources and integrate advanced teaching models. Taking the design and practice of mixed teaching of computer network courses as an example, this paper constructs a new mixed teaching mode through the organic combination of online MOOC, SPOC and offline flipped classroom, which changes the current situation that students listen around teachers and lose the ability of autonomous learning, and enables each student to have their own learning space, and can also form a team to complete projects of interest; It changes the practical problems such as difficult teacher guidance and tight class hours, and enables it to provide students with personalized guidance from cognitive learning to deep learning. Experiments show that this mixed teaching mode has been favored by most students, and has improved learning effectiveness and enthusiasm.

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Design and Practice of Virtual Experiments for Internet of Things Class

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Abstract. Regarding the ability requirements for students majoring in Internet of Things (IOT) engineering, we propose a virtual experiment scheme for IOT system class, which is based on Arduino platform. The virtual experiment includes the process of data sensing, transportation, analysis and visualization. Moreover, the experiments can conduct completely without relying on physical hardware. Thus, the experiments can incorporate with online teaching, which significantly improves the flexibility of experimental organization.

Keywords: Internet of Things · Virtual Experiments · Arduino

1 Introduction

At the beginning of 2020, the outbreak of COVID-19 brought great difficulties to the teaching work of colleges and universities. Many colleges and universities have to resort to online teaching to ensure the normal operation of teaching tasks [5]. However, due to the lack of relevant experimental equipment and conditions, many experimental courses is hard to conduct online and thus can only be delayed until the epidemic situation is alleviated. To meet the demand, virtual experiments are an ideal choice [4]. On this basis, we design and develop a series virtual experiments based related simulators and virtualization tools that covers all the three tiers of IOT architecture, i.e., data sensing, transportation, analysis and visualization, which is able to be conducted online through Internet without relying on dedicated equipment of IOT experiments. The properties of the virtual experiments make it an ideal choice not only to ensure consecutiveness of teaching activities during this epidemic period, but also to promote IOT teaching in colleges and universities that are not well equipped.

2 Objectives of Ability Training

IOT is a new paradigm of the Internet in which various objects attain the ability of being effective parts of the communication networks [3]. To ease teaching and learning, we usually organize the various and diverse technologies of IOT

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systems into an architecture of three layers: perception layer, network layer and application layer [6]. The perception layer, located at the bottom of the three-layer structure, solves the problem of data sensing and acquisition in the human world and the physical world, which is the Foundation of IOT systems. Specifically, the perception consists of various edge devices, sensors, tags and actuators that interact with physical environment. The network layer, connecting the perception layer and the application layer, solves the problem of data transmission. This layer is composed of various private networks, the Internet, wired and wireless communication networks, and is responsible for transmitting the information acquired by the perception layer to the application layer securely and reliably. The application layer, located at the top of the three-tier architecture, is what the user interacts with and is responsible for delivering application specific services to the users. Specifically, the application layer needs to achieve real-time control, accurate management and scientific decision-making for the physical world through data analysis and processing.

The teaching activities of the Internet of Things are organized with respect to the three-tier architecture. In the perception layer, students must learn about various kinds of sensing techniques, such as sensors, QR code, RFID tags and positioning technology. In the network layer, students must learn various communication techniques that varies from wired Ethernet to wireless Wi-Fi, Bluetooth, ZigBee and other communication network technologies. In the application layer, students must learn various data analysis techniques such as data preprocessing, mining and visual display. In the process of teaching, we should not only cultivate students' cognition of knowledge, such as the description of relevant concepts and the understanding of basic principles, but also train students' ability through practice to write relevant codes to complete specific functions at each layer of the Internet of Things. Detailed ability requirements are as follows: 1) In the perception layer, students must master the characteristics and interface access methods of typical sensors, and complete the acquisition of sensor data based on a given hardware development board; 2) In the network layer, students must master typical network protocols and apply these protocols to complete data transmission between nodes in IOT system; 3) In the application layer, students must master techniques of basic data management and analysis, and implement securely data sharing and efficiently data visualization through relevant software platforms.

3 Experiment Design

According to the architecture of the Internet of Things system, we divide the virtual experiments into three levels: 1) the virtual sensing experiments that conducts data perception data in the perception layer; 2) the virtual communication experiments that conducts data transmission experiments in the network layer; 3) the data analysis and application experiments in the application layer.

IOT hardware development board is a critical device during the IOT system experiments. Among the many available platforms, Arduino [1], an open source electronic prototype platform born in Europe, is gradually adopted by everyone. Arduino releases under an open copyright license that allows anyone to produce copies of circuit boards, redesign them, and even sell copies of the original design. Thus, many developers have introduced Arduino into the field of Internet of Things. The good compatibility and expansibility of Arduino can well adapt to different Internet of Things standards. Therefore, we choose to build our IOT system virtual experiments based on Arduino platform.

As a well known teaching conception, objective-oriented teaching requires that teaching activities and strategies should be designed with respect to the objectives of teaching. Based on this concept, we leverage Arduino platform to constructs a series virtualization experiments for perception layer, network layer and application layer of IOT to improve students' knowledge and skills with the objectives of ability training.

The overall design of the virtual experiments of IOT system is shown in Fig. 1. At the bottom, the perception layer mainly utilizes the Arduino virtualization tool *SimulIDE*[1]. The virtual sensor is "plugged" into the virtual development board through the virtual connection, and then the data acquisition is realized through the programming interface of the virtual sensor. The network layer adopts the Virtual Serial Port Driver (VSPD)[2] to realize virtual serial ports on a computer. The we write virtual serial port on both virtual Arduino development board and computer to implement a IOT gateway, which provides data transmission between the virtual Arduino development board and the computer. Through the gateway, the sensing data is collected and stored into the backbone MySQL database. At the application layer, we builds a virtual Web system based on Docker [2], and realizes the visualization of sensor data by writing JSP pages to access the sensor data in the MySQL database. So far, a virtual IOT system with the functions of data acquisition, data transmission, data storage and data visualization has been completely constructed, which covers all the related operations of three-tier architecture IOT system that consists of the perception layer, network layer and application layer.

4 Implementation of Virtual Experiments

This section mainly discusses the implementation of virtual experiment of the perception layer, network layer and application layer of the three-tier architecture. Specifically, the perception layer mainly realizes the simulation of perception data acquisition through the ultrasonic ranging simulation module, the network layer mainly simulates the operation of the gateway through serial port communication experiments, and the application layer builds a virtual Web server to realize the analysis and visualization of data.

[1] https://www.simulide.com/p/home.html.
[2] https://www.virtualserialportdriver.com/.

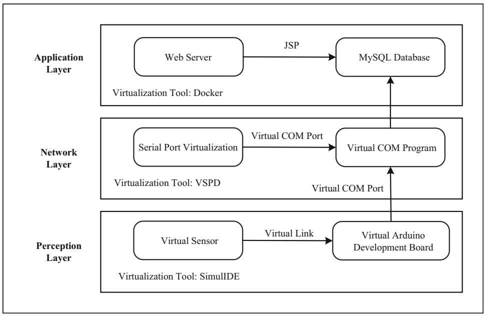

Fig. 1. The Overall Design of Internet of Things System Virtual Experiments.

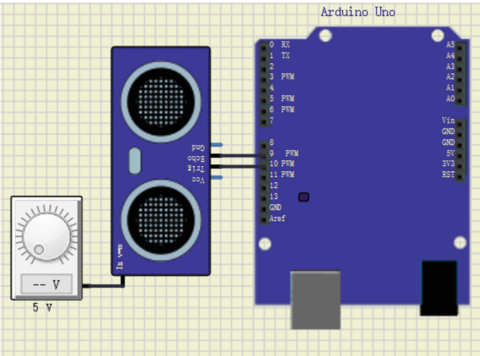

Fig. 2. Wire Connection for Ultrasonic Ranging Virtual Experiments.

4.1 Ultrasonic Ranging Virtual Experiments

In order to realize the virtualization of data acquisition in the perception layer, the Arduino Uno development board and the ultrasonic ranging sensor HC-SR04 are simulated by SimulIDE simulator during the experiment. SimulIDE is an open source real-time electronic circuit simulator that follows the GPLv3 protocol and is free to use. In the process of experiment, we first create an instance of Arduino Uno foundation board in SimulIDE simulation platform, and then create an instance of ultrasonic ranging sensor HC-SR04. The detailed wire connection is shown in Fig. 2.

The SimulIDE simulation platform simplifies the Arduino Uno by retaining only various pins and removing other unnecessary functional components such as reset switches. There are 14 available digital pins and 6 available analog pins on the Arduino Uno basic board. Among the 14 digital pins, pin 0 and pin 1 are used for receiving/transmitting serial data and debugging; pin 2 and pin 3 are trigger interrupt pins, which can be manually set to trigger at both the rising edge or falling edge; pin 3, pin 5, pin 6, pin 9, pin 10 and pin 11 provide pulse width modulation (PWM) Output, which can be used to control voltage and brightness; pin 13 is the interface reserved by Arduino for LEDs testing. The analog pins are mainly used to read the analog signal. There are six analog pins (A0–A5), each of which has a resolution of 10 bits. The analog pins typically accept a signal threshold of 5 V, and the upper input limit can be adjusted by the reference external input pin. The analog pin is capable of converting real-world analog signal, such as analog voltages, into digital quantity by a analog-to-digital converter so that it can be processed by a digital system. In addition, the Arduino Uno can choose its own power supply mode. It has four power supply pins, namely the VIN pin, the 5 V pin, the 3.3 V pin and the GND pin.

HC-SR04 is a common ultrasonic ranging sensor and the only virtual sensor component in SimulIDE platform. The physical HC-SR04 has four pins, which are the power pin, the ground pin, the Trig pin, and the Echo pin. The principle of HC-SR04 is as follows: the Trig pin is a start pin, and as long as a high level voltage (not less than 10 us) is given to the pin, the ultrasonic ranging module starts to work and sends out square waves; the Echo pin is a receiving pin. After the ultrasonic ranging module sends out square waves, the Echo pin will automatically set to a high level until the returned signal is received. According to the time difference, the distance to the obstacle can be calculated based on the speed of sound [7]. The HC-SR04 virtual module has one more pin, i.e., In, which is used for connecting to a voltage source, as shown in Fig. 2. The change of distance is simulated by adjusting the input voltage value, and the conversion unit is 1V/m. Thus, we can manually adjust the range of ranging with an accuracy of 0.01 cm.

The main task of the virtual experiment of ultrasonic ranging is to connect the virtual devices in the SimulIDE platform according to Fig. 2, and then simulate the distance of obstacles by adjusting the analog voltage on the left side. The HC-SR04 virtual module simulates the process of transmitting a square wave by inputting alternate high and low voltage levels to the Trig pin. When the left voltage source generates the distance of the obstacle, the ultrasonic ranging module will "sense" the distance of the obstacle and generate a return signal with a certain time difference at the Echo pin. Since the HC-SR04 virtual module is connected with the virtual Arduino Uno development board, the signal of the Echo pin can be read on the Arduino Uno development board by writing a program, and then the data value of ultrasonic ranging can be obtained after calculation. Thus, the data acquisition experiment of the ultrasonic ranging virtual sensor is completed.

5 IOT Gateway Virtual Experiments

IOT devices can transmit data to each other through Bluetooth, Zigbee, LoRa and other communication modules, but finally the collected data needs to be transmitted to the computer system and saved into database. Therefore, IOT system often deploys a gateway node, which receives data from IOT devices and retransmit it to the Internet or write it into database. Specifically, the gateway needs to implement a communication protocol, listening to the data from the

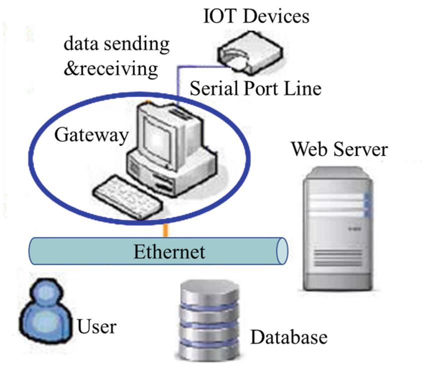

Fig. 3. Gateway in IOT system.

IOT devices, and then extracting the valid data and writing the data into the database. As shown in Fig. 3, the gateway acts as a bridge that connects the IOT devices and the computer system.

The IOT devices are mainly connected with the computer system through the serial port physically, so the virtual experiment of the gateway needs to use the virtual serial port tool VSPD to realize the virtualization of the serial port. VSPD is a virtual serial port tool that runs under Windows. It can create pairs of virtual serial ports. In the view of the external program, these virtual serial ports can communicate in the same way as the physical serial ports. The main difference between the virtual serial port and the physical serial port is that the physical serial port uses the actual hardware circuit for data transmission, and it is a bidirectional port. On the contrast, the virtual serial port is unidirectional, which means that data transmission needs a pair of virtual serial ports to handling data receiving and sending separately.

The second step of the experiment is to develop a serial communication protocol to read data from the Internet of Things device, and then write the data into the database. In the process of serial virtualization, the Arduino Uno board is connected to COM1, and the gateway program needs to connect to COM2. In order to reduce the difficulty of developing the gateway program, the Python language is used in the experiment. Python language provides a rich library interface, which can easily access the serial port and database. The gateway program first uses the Serial() function in the pySerial library to connect the virtual serial port COM2, and sets the relevant parameters consistent with COM1, such as baud rate. Then use readline() Function to read the data from the virtual serial port, and then extract the effective ultrasonic ranging data, and then use the pyMySQL library to write the data into the MySQL database. The first step of the experiment is to realize virtualization of the serial port. The system needs a pair of virtual serial ports COM1 and COM2 for data transmission, which can be realized via “Add Serial Port” in VSPD. After that, the added virtual serial port will appear in the computer device manager. The generated virtual serial ports COM1 and COM2 can communicate with each other, with one receiving data and the other sending data. After the serial ports are added, open the interface of the serial port function of the Arduino Uno board in SimulIDE, and open the serial port COM1 via the encapsulated serial port connection function, which connects the board to COM1. At this time, if the virtual serial port tool shows that COM1 is occupied, it indicates that the Arduino Uno board has been connected to COM1. The "9600-N-8-1" marked on COM1 means that: 1) the communication baud rate of the device connected to the serial port is 9600; 2) the transmitted data does not have a check bit (if there is a check bit, it is generally a parity bit, E represents an even check, and O represents an odd check); 3) the number of bits of the transmitted data is 8, including a stop bit. The baud rate of the serial port can be adjusted, and other parameters are the default parameters. SimulIDE itself encapsulates the function of connecting serial ports, which is also the biggest advantage of SimulIDE compared with other simulation software. That is, SimulIDE provides the simulation circuits with the ability to interact with the outside world, which allows it to support large-scale systems. After setting the connection between the Arduino Uno board and the virtual serial ports, you can write a program for the Arduino Uno board to send the previously collected ultrasonic ranging data to the serial port.

The second step of the experiment is to develop a serial communication protocol to read data from IOT devices, and then write the data into the database. In the process of serial port virtualization, the Arduino Uno board is connected to COM1, and the gateway program needs to connect to COM2. In order to reduce the difficulty of developing the gateway program, we choose Python because it provides libraries with rich functions. Specifically, The gateway program leverages pySerial library. First, the Serial() function is used to connect the virtual serial port COM2, and sets the relevant parameters consistent with COM1, such as baud rate. Then the readline() Function is used to read the data from the virtual serial port, and then extracted ultrasonic ranging data are written into MySQL database by using the pyMySQL library.

6 Web System Virtual Experiments

At present, most of the IOT web systems adopt the B/S architecture, in which users only need to install a browser and all the core business is completed on the server side. Thus, updating and maintenance happens only on the server side, which greatly minimizes the work needed and is suitable for large-scale system.

The main purpose of the Web system experiment is to enable students to 1) master the method of publishing and sharing IOT data, 2) understand the structure and working principle of the Web system, 3) have the skills of Web component installation and environment configuration, 4) be able to design HTML page structure according to the given requirements, 4) write server-side scripts according to the given business logic, and 5) finally realize data visualization.

The key of Web system virtual experiment is to realize the virtualization of Web server. The framework is shown in Fig 4. Firstly, the Web server (Apache

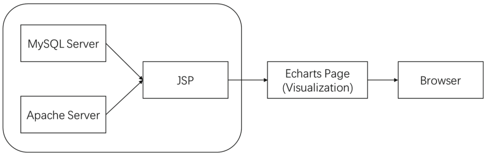

Fig. 4. Architecture of Web system virtual experiment.

Web component) and database server (MySQL system) are virtualized by leveraging Docker container [2]; After that, the business logic of the server is developed by using JSP. The data visualization is realized by using JavaScript open source visualization libraries such as ECharts[3] Finally, users of the IOT system can access the application module through the browser.

6.1 Virtualization of Web Server

For simplicity, we obtain the image of the corresponding Web server and database server via Docket commands. After that, we need to start the corresponding container image and map it to the port of the host (such as port 233). After configuration of the corresponding parameters, the server can be directly accessed through the IP address of the Docker.

6.2 Programming for Server Side

The main work of the server-side programming is handling affairs related to the database, which can be achieved through the JDBC driver components. Specifically, it firstly needs to establish a connection with the database server through the URL of the database server. After that, SQL statements needs to be constructed and submitted to the database server for execution. Finally, it needs to handle the return results from the database server, close the database connection and release the related resources.

6.3 Data Visualization

The data will be visualized in the browser of the client. To do that, we mainly utilize ECharts, an open source visualization chart library in JavaScript, to achieve various data visualization. ECharts was originally open sourced by the Baidu team, following Apache-2.0 open source protocol. It is compatible with almost all browsers, including Internet Explorer 8+, Chrome, Firefox, Safari, etc. ECharts supports most commonly used charts, such as line charts, histograms, pie charts, etc., which enables rich data visualization effects.

[3] https://echarts.apache.org/en/index.html.

7 Effectiveness of Teaching

In the virtual experiment of ultrasonic ranging, since the virtual experiments provides students with consistent experience with physical operations, which allows the students to switch to physical hardware. In the virtual experiment of IOT gateway, students can not only learn the serial communication method, but also master the design and implementation of communication protocol by realizing the interconnection between virtual Arduino Uno development board and computer nodes. In the virtual experiment of Web system, students have a deep understanding of the three-tier B/S architecture by installing and configuring the Web server and database server in the Docker container. The programming training of the data visualization via EChart open source library enables the students to better master the basic skills of data analysis and visualization. In a word, the virtual experiments of IOT system can achieve the same teaching effectiveness as the physical experiments.

8 Conclusion

In this paper, we propose a series of virtual experiments for IOT system teaching by using of virtual tools. The proposed virtual experiments do not rely on dedicated IOT equipment or experiment sites, which is especially suitable for remote teaching during this COVID-19 pandemic. In addition, the proposed virtual experiments can be combined with experiments on physical hardware. By carrying out the IOT experiments on the virtual experiments in advance, students will be quickly familiar with the experimental operations and effectively avoid hardware damage caused by misoperations.

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A Framework of Chinese Vocabulary Smart Fragmented Learning System

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Abstract. Fragmented learning is a learning mode that relies on a ubiquitous learning environment in the era of digital education. Vocabulary learning is a kind of weak systematic accumulation learning task and the fragmented learning mode is suitable for it. In the era of smart education, learning environment perception technology can enhance the environmental suitability of learning resource recommendations in fragmented learning. This paper proposes a framework of Chinese Vocabulary Smart Fragmented Learning System (CVSFLS) which supports Chinese vocabulary fragmented learning driven by idioms learning. AI-based environmental analysis technology, mobile positioning technology, vocabulary knowledge graph and learning resources with learning environmental information enable this system to support smart learning. Fun, multimodal learning resources and an unlimited list of recommended words make learners more addicting in fragmented learning.

Keywords: Fragmented Learning · Smart Learning · Chinese Vocabulary Learning

1 Introduction

Fragmented learning refers to fragmenting the content that learners need to learn, and then using fragmented time for fragmented learning [1, 2]. In the era of digital education, fragmented learning relies on the ubiquitous learning environment to support learners to learn anytime, anywhere [3]. Learning resource recommendation technology is the key technology in fragmented learning system [4, 5]. In the era of smart learning, learning environment perception technology will inevitably improve the environmental suitability of learning resource recommendations in fragmented learning systems. Therefore, the fragmented learning system should be studied in depth in the era of smart learning.

Many researchers focus on the effectiveness of fragmented learning under different learning objectives and learning environments [6–9], and these works lead us to think about the applicability of fragmented learning.

Vocabulary learning and grammar learning are two core tasks of language learning, among which **vocabulary learning is a weak systematic accumulation learning task**. Existing research works apply the concept of smart learning to the field of Chinese

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vocabulary learning [10–12]. Most of these works focus on issues such as knowledge graph construction, words recommendation and learning effect test. There is a lack of research on applying the fragmented learning model to the field of Chinese vocabulary, and there is also a lack of research on integrating learning environment perception and application into the Chinese vocabulary fragmented learning system.

2 Chinese Vocabulary Smart Fragmented Learning System

We believe that the fragmented learning model is suitable for vocabulary learning. This is because:

- Vocabulary learning is not systematic, and it needs to be accumulated over time. Fragmented learning, as an informal learning mode, is suitable for this kind of learning tasks.
- In the new media environment, multimodal vocabulary learning resources can arouse great interest of learners.
- Each learner's vocabulary learning path is different. In general, after mastering the basic vocabulary and basic grammar of a language, learners can gradually improve the language level by listening or reading learning materials with suitable difficulty.

The learning content and resources in a Chinese vocabulary fragmentation learning system must be able to arouse the interest of learners. If learners can be reluctant to put down their mobile devices, then they can roam freely in the ocean of learning resources and improve their language level unconsciously.

So, we devise a system to support Chinese words fragmented learning driven by idioms learning. Chinese idioms have stories and are the living fossils of Chinese. They are rich in Chinese cultural knowledge. Such interesting learning content provides a guarantee for the interestingness of learning resources. But for a language learner, especially a second language learner, idioms are not easy to learn. On the one hand, most idioms use extended meanings rather than original meanings, which language learners often fail to understand when reading or listening to idiom explanations. On the other hand, idioms are rich in single-character morphemes in ancient Chinese. Language learners, who take modern Chinese as their learning objects, are not sensitive to single-character morphemes. Teachers usually expand ancient Chinese single-character morphemes into modern Chinese multi-character words or phrases to make learners understand. Therefore, the idiom-driven Chinese vocabulary learning system should also take non-idiom modern Chinese words as the learning objects, so that the system can set up learning steps for learners to learn idioms.

The learning environment perception technology in the smart learning system is beneficial to recommend idioms and example sentences. We can recommend the idiom "天府之国" (means "the land of abundance") for learners in Sichuan, and the idiom "走马观花" (means "look at the flowers while passing on horseback, to glance over things hurriedly") for learners in Shaanxi; recommend the idiom "花好月圆" (means "blooming flowers and full moon") for learners on the Mid-Autumn Festival, and the idiom "老当益壮" (means "old but vigorous") for learners on the Double Ninth Festival. When learners learn the noun "花" (means "flower"), we can recommend the example sentence "公园里的花很漂亮。" (means "The flowers in the park are very beautiful.") for learners who are outdoors, and the example sentence "窗台上有一盆花。" (means "There is a pot of flowers on the windowsill.") for learners who are indoors.

3 System Design

In this part, we propose a framework of Chinese Vocabulary Smart Fragmented Learning System (CVSFLS) and describe the different components in detail. Figure 1 depicts the system framework. Learners use mobile devices to access this system. The server includes five modules which are Web API module, learner behavior recording module, vocabulary recommendation module, learner behavior analysis module and environment analysis module. Also, learner behavior data, learner portraits, vocabulary knowledge graph and learning resources are four kinds of data on the server.

3.1 Mobile Client

The client should run on mobile device in order to support ubiquitous fragmented learning. Also, it best run on some popular open platform, such as WeChat. The open platform can provide basic functions for mobile application development, including user authorized login, getting location information. The CVSFLS client has the following main functions.

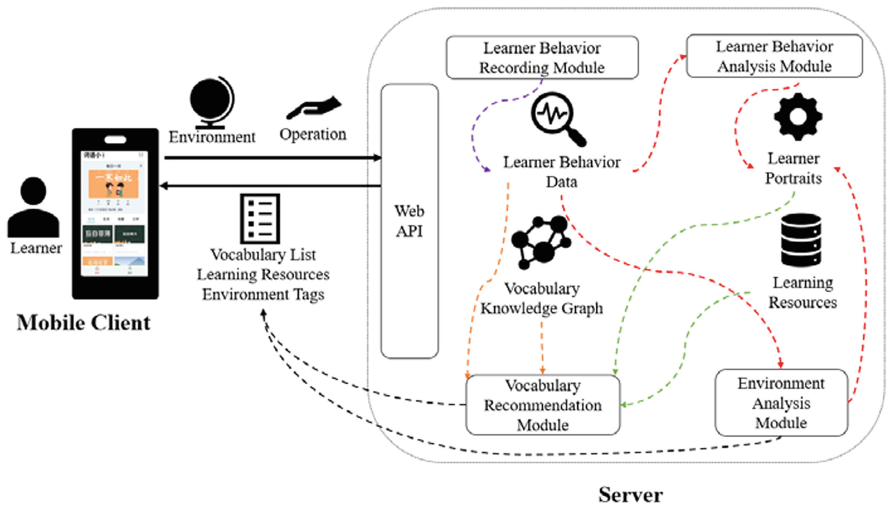

Fig. 1. Framework of CVSFLS.

Collecting Learning Related Data for AI-Based Learning Analysis. The data includes learning environment information and learning behavior data. Learning environment information includes location information and the learner's surrounding environment, which can be analyzed by photos. Learning behavior data includes all actions that the learner interacts with the system, such as logging in, learning words, adding favorites, posting comments. All the above information is uploaded to the server in real time, making CVSFLS a 'digital twin' of the learning process and the learning environment. Then the system can recommend personalized words to the learner.

Providing Various Types of Information Touchpoints. Information touchpoints carry a certain amount of knowledge information in a certain form, and attract learners to explore [3]. Rich types of information touchpoints are conducive to stimulating learners' interest in learning and prolonging the fragmented learning time. The CVSFLS provides the following three types information touchpoints.

- Recommendation words, which include daily recommendation, homepage recommendation, word-related recommendation on the word learning page and search-related recommendation on the searching result page.
- Tag-based idioms aggregation. Idioms have knowledge tags——source literature, related persons, related festivals, related places, etc. When a learner browses an idiom learning page, the page should provide knowledge tags, related to this idiom, linking to all idioms marked with the certain knowledge tag.
- Personalized learning records: learned words, favorites, new words and learning history. Learners can easily access the words they have learned from the entries in the personalized learning record.

Aggregating Multimodal Learning Resources. For a word item, learning resources, such as text, images, audio and video, are effectively gathered in the learning UI. It is convenient for users to focus on learning a word in fragmented time.

Social Learning. Learners can publish notes as they learn words, and these notes can be seen by all learners.

3.2 Web API Module

The Web API receives the data uploaded from the mobile client and returns the information required by the client according to the context of the learner's operation. Table 1 lists different types of learner operations, the uploaded data from the mobile client and the returned information from the server.

3.3 Learner Behavior Recording Module and Learner Behavior Data

The learner behavior recording module stores the data from the mobile client and the timestamp as **the learner behavior data** on the server, which are used to construct user portraits and learning recommendation. Learner behavior data is a storage that is only added but not deleted, and its details are listed in the "Uploaded Data" column in Table 1.

Table 1. Types of Uploaded Data and Returned Information.

Learner Operation	Uploaded Data	Returned Information
Log in	Learner ID, learner location	The daily word, a collection of recommended words[a] on the homepage, the location label and the language level label in the learner portraits
Search a word	Learner ID, learner portraits, searching string	Searching results, a collection of recommended words on the search page
Take a photo	Learner ID, learner portraits, a photo	The daily word, a collection of recommended words on the homepage, the location label, the language level label and the environment label in the learner portraits
View personal learning records, including: "Favorites", "Learned", "New Words" and "Learning History"	Learner ID, learner portraits, action type includes viewing personal "Favorites" or "Learned" or "New Words" or "Learning History"	A words collection for a certain learning record of the learner
View the word learning page	Learner ID, learner portraits, target word ID, page type and related ID before entering[b]	Learning resources[c] for the word that match the learner portraits, word knowledge tags, recommended words collection on the word learning page
Switch learning resources on the word learning page	Learner ID, learner portraits, the word ID, the source resource ID, the target resource ID	None
Click the knowledge tag of the word on the word learning page	Learner ID, learner portraits, the word ID, the knowledge tag ID	A idioms collection related to this knowledge tag
Add the word the learner is learning as "Favorites", "Learned" and "New Words", or cancel the previous "Favorites", "Learned" and "New Words"	Learner ID, learner portraits, the word ID, the operation type[d]	None

(*continued*)

Table 1. (*continued*)

Learner Operation	Uploaded Data	Returned Information
View notes for a word	Learner ID, learner portraits, the word ID, the operation type is "View Notes"	All notes of this word
Publish learning notes	Learner ID, learner portraits, the word ID, the operation type is "Publish Notes", and note content	All notes of this word
View related stories of an idiom	Learner ID, learner portraits, the word ID, the operation type is "View Stories"	Related stories of the idiom

[a]The words collection contains a series of words and the Chinese word form, the English explanation and a related picture of each word.
[b]The page type and related ID before entering a word learning page include daily word, homepage recommended words, the recommended word on a certain word learning page and source word ID, some personalized learning record page, some knowledge tag aggregation idioms page and the knowledge tag ID, word searching results, recommended word on the searching result page.
[c]Learning resources for a certain word include Chinese and English explanations, Chinese example sentences and English translations of example sentences, pictures explaining the word, and videos related to the word.
[d]Operation types include "Add Favorites", "Cancel Favorites", "Add as New Words", "Cancel New Words", "Add as Learned", and "Cancel Learned".

3.4 Learner Portraits

In CVSFLS, learner portraits include the learner's Chinese level and the diachronic learning environmental labels.

The Chinese level labels include reading level, listening level and vocabulary output level. And these labels are obtained by the learner behavior analysis module based on the learner behavior data.

The diachronic learning environmental labels, which are listed followed, are mined by the environment analysis module based on the time, the learner's location information and photos taken by the learner.

- Time labels related to learning time, such as festivals, solar terms.
- Location labels where the learner logs in the system each time. These labels are the province name of contemporary China.
- Place labels, such as outdoors, playgrounds, parks, hospitals, classrooms, libraries.

Time labels and location labels affect the results of recommended words. Chinese level labels and place labels affect learning resources pushed to a learner.

3.5 Learner Behavior Analysis Module

The learner behavior analysis module predict a learner Chinese level based on the learner behavior data. The learner behavior data record every operation. We can know the time when a learner read, watch or listen to each learning resource. Combined with the analysis of text reading difficulty and listening text difficulty, we can get the appropriate reading level and listening level of a learner. Also, if a learner publishes learning notes, we can know the vocabulary output level of the learner.

3.6 Environment Analysis Module

The environment analysis module analyzes the time labels, location labels and place labels in learner portraits.

In the vocabulary knowledge graph of CVSFLS (see section G of this part), some idiom links to festivals, solar terms or provinces. The environment analysis module determines the time label according to the learning time, analyzes the location label based on the learner's location information.

Some example sentences have place tags, such as outdoor-park, outdoor-street, indoor-supermarket, indoor-hospital, indoor-classroom. The environment analysis module performs scene recognition according to the uploaded image to determine the place labels.

When the learner logs in, or no time label and no location label uploaded by the client, this module analyzes the time label and the location label. When the user takes a photo, this module analyzes the place label. The time label and the location label are only valid in one session, and the place label is updated each time a photo is taken.

3.7 Vocabulary Knowledge Graph

Knowledge graph is a technical solution for domain knowledge modeling. The knowledge graph in the CVSFLS aims to serve the fragmented learning of Chinese words driven by idioms learning. The nodes in the knowledge graph are divided into **learning object nodes** and **knowledge label nodes**. The learning object nodes include idioms and non-idiom modern Chinese words. And these nodes will be the recommended learning objects. The knowledge label nodes are cultural knowledge related to idioms, including source literature, related persons, related festivals, event dynasties, related locations, etc.

Figure 2 is a knowledge subgraph. The red nodesare the learning object nodes, including idioms and modern Chinese words. The edges between the modern Chinese word nodes and the idiom nodes are red. The dark red nodesare the idiom knowledge label nodes related to time and places, for example: the event location of the idiom allusions and the contemporary province to which the location belongs, festivals, solar terms, event dynasties, etc. Other knowledge label nodes are blue nodes, including: source literature, source literature author, idiom sentiment polarity, related persons, etc. Figure 2 shows the knowledge sub-graph related to the seven idioms of "走马看花" (means "look at the flowers while passing on horseback, to glance over things hurriedly"), "雪泥鸿爪" (means "a swan's footprints found on snow and mud"), "乘龙快婿" (means "a handsome son-in-law"), "一寒如此" (means "as poor as Job's turkey"),

“深谋远虑” (means “think in depth and plan carefully”), “天府之国” (means “the land of abundance”), and “雾里看花” (means “see flowers through a mist”).

Table 2 lists the one-hop relations of idioms “走马看花” and “雾里看花” in Fig. 2. “走马看花” has 6 one-hop relations, and “雾里看花” has 11 one-hop relations.

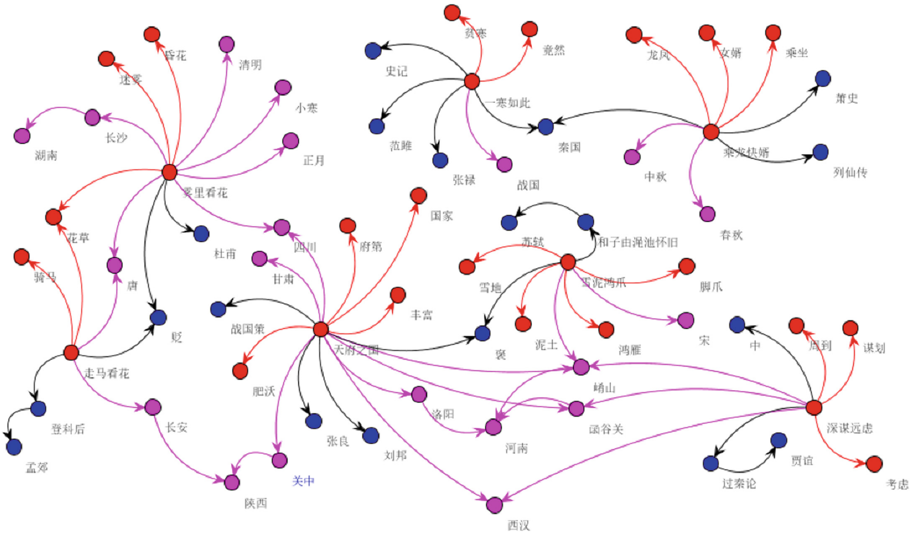

Fig. 2. Sub-graph of vocabulary knowledge graph with node-labels and without edge-labels. (Color figure online)

3.8 Vocabulary Recommendation Module

The vocabulary recommendation module includes three parts: a recommendation submodule based on deep learning, a recommendation post-processing module and a learning resource selection module.

The deep learning-based recommendation submodule uses KGCN [13]. This is a recommendation algorithm based on knowledge graph, and the training data set includes knowledge graph and “user-item” historical data. The trained recommendation model takes a certain word as input, and the recommended words list is output. The “expert annotation plus questionnaire” method is used to generate the initial “user-item” data, and then the initial recommendation model is obtained by training. After the system is online and running, the recommendation model is regularly trained.

The post-recommendation processing module re-ranks the recommendation words based on the time labels and location labels in the learner portraits, so that the idioms with high spatial and temporal matching with the learner can be ranked better.

The learning resource selection module selects learning resources based on the learner’s Chinese level labels and the place labels. For example: (1) select explanations, example sentences, idiom stories, and videos with appropriate difficulty based on

Table 2. One-hop relations of idioms " 走马看花" and " 雾里看花" in Fig. 2.

Head Node	Relation	Tail Node
走马观花	Related word	花草(means "flowers and grass")
走马观花	Related word	骑马(means "ride a horse")
走马观花	Dynasty	唐(means "Tang Dynasty")
走马观花	Location	长安(means "Chang'an, the capital of the Tang Dynasty")
走马观花	Source literature	《登科后》(means "《After Receiving Government Degrees》")
走马观花	Sentiment polarity	贬(means "negtive")
雾里看花	Related word	花草(means "flowers and grass")
雾里看花	Related word	迷雾(means "dense fog")
雾里看花	Related word	昏花(means "dim-sighted")
雾里看花	Dynasty	唐(means "Tang Dynasty")
雾里看花	Location	长沙(means "Changsha, a city in Hunan province")
雾里看花	Location	四川(means "Sichuan province")
雾里看花	Time	正月(means "the first month of the lunar year")
雾里看花	Solar term	清明(means "Qingming, one of the 24 solar terms in China")
雾里看花	Solar term	小寒(means "Slight Cold, one of the 24 solar terms in China")
雾里看花	Sentiment polarity	贬(means "negtive")
雾里看花	Person	杜甫(means "Du Fu, a famous poet of the Tang Dynasty")

the learner Chinese level labels; (2) select appropriate example sentences based on place labels.

4 System Implementation

This part shows a WeChat-APP-based CVSFLS. The server components are developed using Java Spring framework. The vocabulary knowledge graph is stored in Neo4j, and the other data are stored in MySQL and the file system.

Figure 3 lists some UIs of CVSFLS client. (a) shows the daily word and the recommendation words on the homepage. (b)(c)(d)(e) show four types of personal learning

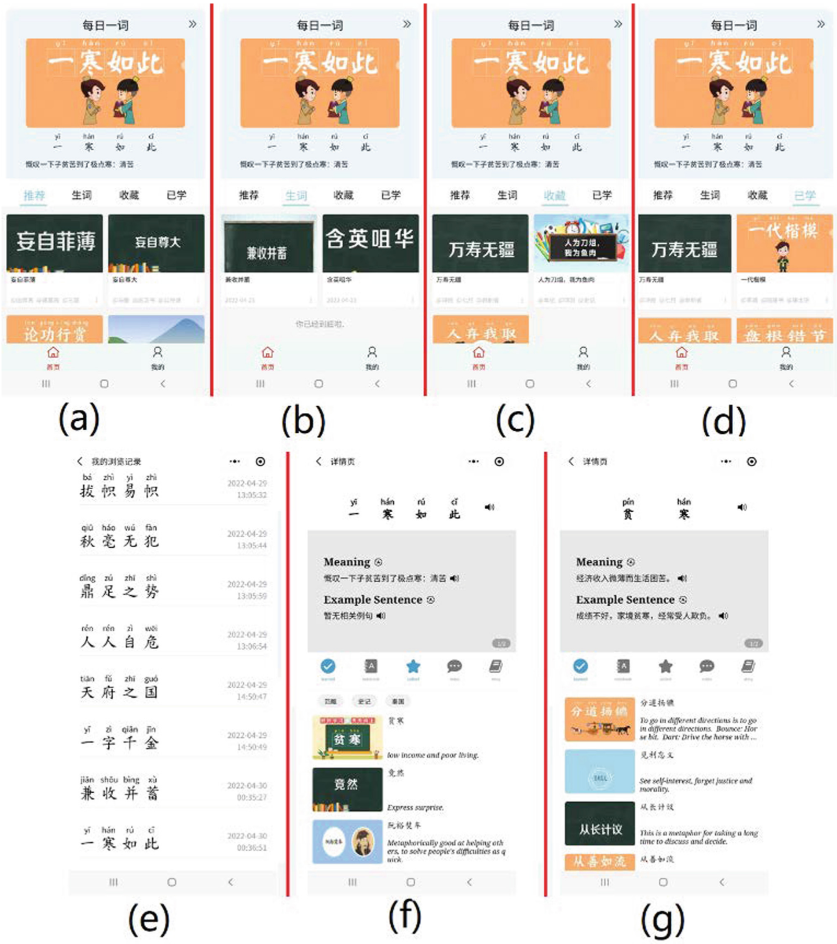

Fig. 3. Mobile client UIs of the CVSFLS WeChat APP.

records: new words, favorites, learned words and learning history. The learning history page can be accessed in "我的" (means "mine") page. (f) and (g) are word learning pages. In the word learning page, learners can click the "learned", "favorite", "notebook" buttons to add the word into the learned words list, favorite words list or new words list; click the "note" button to view and publish learning notes; and click the "story" button to read stories of the word. The gray background-color area displays word learning resources, and learners swipe left or right to switch learning resources. Click the speaker buttons to play the automatically synthesized speech. In idiom-word learning page, such as "一寒如此" (means "as poor as Job's turkey"), there are knowledge tags under the learning resources area, and learners can browse tag-based idioms aggregation page by click the tag. In all pages with recommendation words list, learners can swipe up for more words and never reach the page bottom.

5 Conclusion

This paper proposes a Chinese Vocabulary Smart Fragmented Learning System (CVS-FLS) which supports Chinese words fragmented learning driven by idioms learning. Learner environment perception technology based on mobile positioning and scene analysis to support smart learning. The interestingness of idiom stories, the multimodality of learning materials, and the infiniteness of recommended words can make learners more addicted. The integration of non-idiom modern Chinese words into the idiom learning process can set up steps for Chinese as a second language learners (CSLs) to learn idioms under the guidance of the "i + 1" language acquisition theory.

The framework of CVSFLS and the initial software have been given, and knowledge engineering and learning resources engineering related to this system are important follow-up work. The construction of high-quality vocabulary knowledge graph for the target application of this system, and the acquisition and generation of vocabulary learning resources need to be further studied.

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Design of Chinese Grammar Smart Learning System

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Abstract. Grammar is an essential component of language instruction. In the existing grammar learning applications, there are several aspects needed to improve, such as the cold start problem, fixed learning path, less effective learning videos, undifferentiated material presenting, and low-quality exercises. With the purpose of making some useful attempts, we have built a Chinese Grammar Smart Learning System (CVSLS). Through the initial assessment and pre-learning test, the system can identify the weak areas of learners. After taking the factors of grammar difficulty, arrangement pattern and learning condition into consideration, the system can provide for each learner a personalized learning path. Assisted by the well-designed videos and exercises, learners can better master grammar knowledge. In addition, the dynamically adjusted presentation of learning materials based on influence value and demand value can achieve a better learning experience and improve the learning efficiency.

Keywords: Grammar learning · Learning strategies · Learning materials

1 Introduction

Grammar is an important part of second language learning. Compared with students who learn a language in natural environment, those students who receive classroom grammar instructions have essentially the same acquisition sequence and are able to acquire higher grammatical competence in general [1]. Therefore, the teaching method is so crucial that it can affect the quality and effectiveness of grammar learning [2, 3].

In addition to traditional classroom teaching, learners can also use a mobile app or follow a MOOC to learn Chinese grammar. We conducted research on current language learning software and online courses. We found that the software of foreign language learning is more than Chinese language and most of them is focused on vocabulary learning rather than grammar learning. Also, there are a small number of Chinese courses for learning grammars on MOOC platforms such as the Coursera, Udacity, edX, unipus and icourse163, however, they share the common flaws with the apps: (1) The order

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in which the grammar items are presented is not very scientific. The knowledge points are simply listed there, some of them are even in the phonetic order of grammar names, without following the Chinese proficiency grading standards [4] or the acquisition order. This kind of navigation is not conducive to learners' grammar acquisition. (2) Video is the primary teaching method, yet most of the explanations are copied from textbooks or grammar books. This lack of instructional design affects the understanding and learning. (3) The system is unable to dynamically adjusted the presentation of learning resources according to learners' needs and learning strategies, and the user's experience is unsatisfied. (4) Due to the lack of grammar items organizing and pre-learning assessment, learners are unsure which language point they are best suited to learn. (5) The exercises are insufficient and without hierarchy. Also, the lecturing and practicing of current grammar disconnect with the previously learned ones.

In order to improve the grammar learning efficiency for Chinese Second Language learners, we have constructed a Chinese Grammar Smart Learning System (CGSLS) which manages to achieve these goals: (1) The grammar knowledge map is constructed based on the grammar grading standard [4] and attributes such as difficulty, structural relationships, and knowledge of preceding and following terms. It will enable learners to learn grammar points in a consistent order that follows the laws of acquisition and cognition. (2) Since grammar explanation is the most important part of grammar learning [2], we have designed videos that conform to the language teaching principles to help learners comprehend grammar better. (3) The system can deliver customized learning materials based on the calculation of influence factors and user behavior data. (4) Through the initial assessment and pre-learning test, the system can accurately identify learners' knowledge blind spots and provide the grammar they need to learn. (5) The sufficient well-structured and designed exercises will assist students in better practicing grammar points and improving their learning.

2 The Chinese Grammar Smart Learning System (CGSLS)

CGSLS mainly consists of three modules: (1) the user module, which stores learners' personal information and learning data; (2) the domain module, which contains the grammar knowledge map and learning materials; (3) the strategy module, which stores the running rules of the system.

The construction of grammar points in CGSLS is based on the Chinese Proficiency Grading Standards for International Chinese Language Education [4]. This syllabus is issued by the Ministry of Education of the People's Republic of China. It divides learners' Chinese proficiency into three levels from low to high. Since most syntactic structures appear in the elementary level, we selected all the grammar structures from level one, with a total of 100 grammar points, as the learning objects in CGSLS.

CGSLS uses a combination of system-driven and learner-driven approach. Based on the learners' test results, the system can deliver individualized learning materials and learning sequences; however, learners can also choose their own target leaning points and materials based on their needs, interests, and learning habits.

The registered users of CGSLS can continue from their precious learning contents. If this is their first time using the software, they can either take the initial test or choose one item to begin. The system can analyze the knowledge points that the learners failed to master in the initial test and present them with one grammar to study. Learners have the option of skipping that grammar and demanding a new one or make it as the current learning subject. The learning process includes three stages: a pre-learning test, the grammar learning, and a post-learning exercise.

3 The Grammar Knowledge Map

A knowledge graph for adaptive learning systems should have two characteristics. Firstly, it should have refined knowledge points, with smaller granularity that can better adapt to different learners and increase intelligence. Secondly, it should have accurate relationships between knowledge points. The more precise the description of relationships between knowledge points, the more the system can push content that conforms to learning patterns, leading to better learning outcomes. According to literature and platform research, Chinese grammar knowledge graphs that meet these conditions are relatively rare. Most grammar learning platforms take content directly from textbooks without further splitting and integration of knowledge points. Due to the lack of in-depth exploration and analysis of knowledge points themselves, the system cannot recommend learning content to learners based on the internal relationships between knowledge points, but rather follows the order of chapters in textbooks, resulting in lower adaptability. Therefore, to improve the adaptability of grammar learning on the platform, a grammar knowledge graph needs to be constructed. The specific approach is as follows:

Firstly, analyze language points. Referring to relevant research results, language points can be divided into major and minor language points. Major language points are generally more complex in structure, have larger semantic capacity, and have higher language difficulty, specific restrictions, and precautions, such as complements, structural particles, dynamic particles, and "ba" structure in Chinese. In contrast, minor grammar points have simpler structures and rules, such as sentence structures, adverb positions, and conjunctions in complex sentences. The purpose of labeling language points as major or minor is to create a reasonable learning interval and form a scientific and personalized learning path, which will be explained in the following text.

Secondly, define the data attributes of knowledge points. Data attributes are the properties of knowledge points themselves, including the structure, semantics, function, and difficulty of grammar knowledge points. For major language points, there is a lot of research on language acquisition. We can arrange these large language points according to the order of acquisition and assign difficulty values. For minor grammar points, due to lack of existing acquisition order, we use the methods from the acquisition research, which is calculating the correct usage rate. We ranked the related questions of these grammar points from 276 students' final exam papers, and the language points with higher correct rates have lower difficulty values, while those with lower correct rates have higher difficulty values.

Thirdly, define the object properties of knowledge points. Based on the characteristics of language points and the needs of adaptive learning, we define four types of relationships between grammar knowledge points: predecessor-successor, association, similarity, and parallel, as shown in Fig. 1.

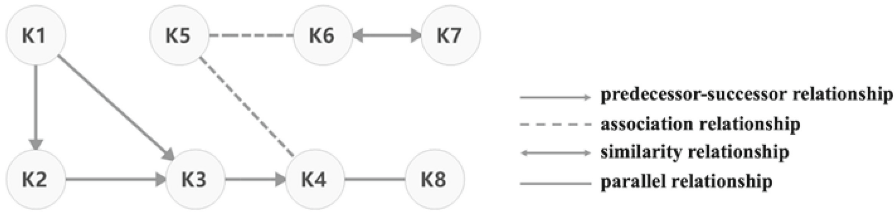

Fig. 1. The four relationships between grammar knowledge points.

The relationship between knowledge points K1 and K2 is a predecessor-successor relationship, indicating that there is a temporal order between the two knowledge points during learning. The predecessor-successor relationship is mainly based on the syntactic structure of language points, where the syntax of the preceding knowledge point is usually a subset of the syntax of the succeeding knowledge point. Learners need to master K1 first before learning K2 effectively. The predecessor-successor relationship has transitivity, meaning that if K2 is the predecessor of K3 and K3 is the predecessor of K4, then K2 is also the predecessor of K4.

Knowledge points K4 and K5 have an association relationship. The association relationship is mainly based on the structure and semantics of language points and connects language points that are prone to systematic errors during learning based on the error analysis research. The association relationship has symmetry and transitivity. If K4 and K5 have an association relationship, then K5 and K4 also have an association relationship. If K5 and K6 have an association relationship, then K4 and K6 also have an association relationship.

Knowledge points K6 and K7 have a similarity relationship. Knowledge points that have a similarity relationship have certain similarities in the syntactic structure, semantic expression, or pragmatic function of language. The similarity relationship also has symmetry and transitivity.

Knowledge points K4 and K8 have a parallel relationship, which means that they do not have a temporal order in learning, and the order in which K4 and K8 are learned does not significantly affect the understanding and mastery of that knowledge. The parallel relationship also has symmetry and transitivity.

Finally, we built a database, labeled the data and object properties of knowledge points, and imported it into the Protégé software to obtain the grammar knowledge map.

4 Strategies of Grammar Learning Paths

The grammar learning paths in CGSLS are determined by the grammar difficulty, arrangement pattern and learning condition.

4.1 The Grammar Difficulty Sequence

In general, one language is learned in an order from easy to difficult [5]. In the constructed grammar knowledge map of this paper, knowledge points are arranged according to their difficulty values, forming a difficulty sequence for these points. Learning the language points with lower difficulty first, followed by those with higher difficulty in accordance with the sequence, conforms to the law of language acquisition and can ensure learning effectiveness.

The difficulty of language points is reflected in their accuracy rate, with language points having a higher accuracy rate being easier to learn, while those with a lower accuracy rate being more difficult. The difficulty sequence of knowledge points in this system is not fixed, but dynamically adjusts according to the learners' accuracy rate in answering the questions. The lower the accuracy rate of the exercise questions related to a knowledge point, the greater the difficulty of that knowledge point, and its position in the difficulty sequence will be adjusted further back, until the learners have accumulated enough knowledge before learning it, thereby ensuring learning success and protecting the learners' confidence.

4.2 The Grammar Arrangement Pattern

In the teaching arrangement of grammar items, difficult knowledge points should be organized in a scattered manner to avoid concentrated learning. Staggering difficult grammar items with easier ones will provide a buffer period for learners to digest the tough learning points [6]. In the grammar knowledge graph, language items are categorized into major and minor knowledge points according to the factors such as difficulty, complexity and semantic capacity. According to the principle of dispersing difficult points, the major knowledge points are taken as nodes in the grammar learning path, and the minor ones are arranged equally in the intervals. In this system, there are a total of 30 major grammar points and 70 minor grammar points. Based on the 30 major grammar points as nodes, there are 29 intervals, with an average of 2.4 minor knowledge points that can be arranged in each interval. Following the strategy of selecting positive integers, the arrangement of minor knowledge points is "2 minor knowledge points - 3 minor knowledge points - 2 minor knowledge points - 3 minor knowledge points… 2 minor knowledge points - 1 minor knowledge point". According to this arrangement, the minor knowledge points are inserted into the intervals between the major knowledge points, which forms the arrangement pattern of the knowledge points. Then, the specific knowledge points are arranged according to the difficulty sequence, therefore we obtain the initial learning sequence of the knowledge points.

4.3 The Grammar Learning Condition

When the grammar difficulty sequence and arrangement pattern are accomplished, the relative learning order of knowledge points is determined. However, if the system assigns knowledge points to learners in this way, it becomes a fixed learning order again. To provide individualized learning, we also need to consider the learning conditions of grammar items.

In the grammar knowledge graph, the attributes of each knowledge also include the vocabulary and grammar learning conditions. The vocabulary learning conditions refer to the core vocabulary required for learners to learn the grammar point and complete the exercises; and the grammar learning conditions are the preceding knowledge of that grammar point.

In the grammar arrangement pattern, the major knowledge points generally have a predecessor-successor relationship, and their learning order is usually fixed, while the minor knowledge points generally have a parallel relationship, and their learning order can be adjusted according to the learner's level. When the system detects that the learner meets the learning conditions for certain grammar points, those grammar points can be learned first. For example, the learning order combining grammar difficulty and grammar arrangement pattern is "MaK - MiK - MiK - MaK - MiK - MiK – MiK - MaK (MaK represents major knowledge point, MiK represents minor knowledge point)." Learner 1 meets the vocabulary and grammar learning conditions for MaK1 (numbers represent knowledge point identifiers), MaK2, MiK1 and MiK5, while Learner 2 meets the learning conditions for MaK1, MaK2, MiK2, MiK4 and MiK5. Therefore, Learner 1's grammar learning sequence is "MaK1 - MiK1 - MiK5 - MaK2" and Learner 2's grammar learning sequence is "MaK1 - MiK2 - MiK4 - MaK2 - MiK5". When Learner 2 meets the learning conditions for Mi1 and MiK3 during the learning process, the system recommends this knowledge point to him, and his learning path becomes "MaK1 - MiK2 - MiK4 - MaK2 - MiK5 - MiK1 - MiK3".

Therefore, we can see that since each learner has a varied vocabulary and grammar knowledge, the grammar items that they can learn are also different. When these suitable learning points are organized by their difficulty ranking and the arrangement pattern, one personalized learning path is generated for each learner.

5 Design of Grammar Explanation Videos

The video integrates texts, images and sounds, which can stimulate learners' interest in learning. Breslow investigated learning activities in MOOCs and discovered that learners spent most time on video resources, which is an important way for learners to acquire knowledge [7]. Therefore, the design of videos on platform has a significant impact on learning results.

According to our survey of 85 students, 72 of them (84.7%) like watching video when they learn a new grammar item and 56 people (65.9%) admit that the preferred video duration is shorter than 3 min. As a result, the grammar explanation videos should be made within 3 min to maintain learners' interest and attention.

Constructivism theory believes that learning is not the process of teachers passing knowledge to learners, but that learners build new knowledge on the basis of existing knowledge with the help of others and necessary learning materials [8]. During this process, situation, collaboration, meaning and conversation are the four key elements in the learning environment. Therefore, the most essential grammar teaching resource on the platform, grammar video, should play a role in creating scenarios, guiding learning, clarifying meaning, and initiating conversations in addition to delivering knowledge.

Based on the constructivism theory [8] and the grammar teaching mode of traditional classroom [9], the design of grammar teaching video should include the following six components:

(1) Create scenarios and present problems. New knowledge should be placed in a specific situation and connected with learners' existing knowledge or experience. By asking them how to solve a real-life problem or how to express the relevant content in Chinese, it can stimulate their interest and motivation in learning and provoke them to participate in the construction of new knowledge.
(2) Guide learning and demonstrate grammar. Learners need access to relevant learning aids and materials in order to build new knowledge into their own system. In this demonstration session, learners are assisted by scenarios to comprehend the structures, semantics, and functions of the new grammar. In this way, learners can accumulate perceptual understanding before the grammar is explained.
(3) Clarify meaning and explain grammar. After learners have initially formed a new cognitive knowledge, in order to ensure its accuracy, teachers need to provide relevant materials to help learners further adjust and consolidate it. In the grammar explanation session, the structures, semantics and functions of the grammar item are illustrated, so as to develop learners' cognition to rational cognition.
(4) Initiate conversations and solve problems. In learning platforms, static teaching resources could make learning tedious and difficult to persist, so it is very important to make a good interaction. Only through an adequate number of interactions, such as question-and-answer, exercises and feedback, can learners' attention be promoted and learning tasks be completed [10]. Different from traditional classroom teaching, online teaching is difficult to initiate instant conversation between teachers and students, so it mainly adopts the mode of throwing out questions, providing thinking space, and giving answers to realize the interactions. In the grammar video, it first uses real-life questions to stimulate learners' thinking, and after learning the core contents, the answers are given in the problem-solving session. It will evaluate whether learners have mastered the relevant contents and completed the construction of the new knowledge.
(5) Give Real-life scenario examples. A whole learning process should include the application of knowledge to real-life situations. After learners have completed the knowledge construction, they should be shown an application clip so that they may absorb the new knowledge more deeply and comprehend how to use it in a real-life circumstance.
(6) Summarize and interact. The final part of the grammar video reviews and reinforces the teaching content and provides extensions and interactions to consolidate learners' impressions of the newly learned content, as well as to test whether learners have achieved the learning goals.

In addition to suiting the characteristics of online learning, grammar videos should also meet the needs of adaptive learning platforms. Different learners have different learning habits. Some tend to watch the complete video, while others prefer to learn in pieces. After making the video, it should be reasonably divided and tagged, so that learners can locate the needed parts more easily. Figure 2 shows one sample of the video which is marked corresponding to the six sessions discussed above.

Fig. 2. An example of the grammar learning video.

6 Strategies of Presenting Learning Materials

Regarding the learning resources, each grammar item contains explanation texts, structures, one instructional video, and example sentences with translations and audios. Figure 3 shows a grammar learning interface.

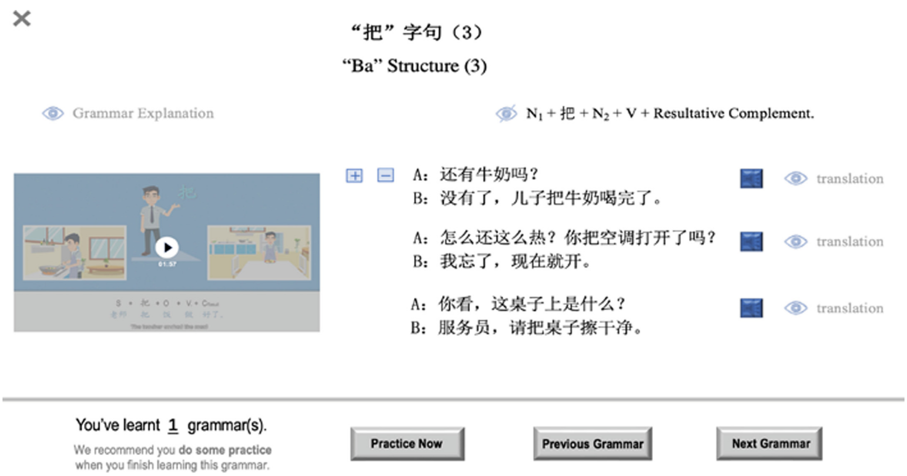

Fig. 3. An example of the grammar learning pages.

The Chinese and English names of the target learning grammar are displayed at the top of the page. According to the average weight value of the resources, which will be discussed below, the grammar explanation texts are in the initial concealed state on the page, while the grammar structures are in the initial shown state. Learners can view the grammar instructional video on the left side, and they can follow the set segmentation points to find the part they need or are interested in. The texts, audios, and translations of the language examples can be found on the right side of the page. The number of examples displayed is initially set to three, but learners can change this by clicking the Add or Subtract button. During the learning process, learners can click on the Previous Grammar or Next Grammar buttons to learn other items, they can also go to the practice session by clicking on the Practice Now button.

Each resource is measured by three important indicators: impact value, demand value and average weight value [11]. The impact value is determined by teachers. We invited 10 Chinese language teachers with more than 8 years of teaching experience to rate the impact of each resource on learning outcomes on a scale of 1 to 10, with 1 being the lowest and 10 being the highest. The average score given by teachers represents the impact value of the resource. For example, the impact value of grammar example 1 is 0.91. The demand value is determined by learners. We collected data on the demand for each resource through a survey, and calculated the demand value by dividing the number of people who use the resource by the total number of participants. For example, the demand value of grammar example 1 is 0.64. By averaging the impact value and demand value of each resource, we obtained the average weight value of the resource. For example, the average weight value of grammar example 1 is 0.775. This value integrates the expertise of teachers and the learning needs of students, and serves as a basis for determining whether a resource should be presented to learners.

We set the threshold of presenting the learning resource at 0.5. Resources with an average weight value greater than 0.5 will be initially displayed on the page, while those with an average weight value less than 0.5 will be initially hidden on the page.

In order to realize the personalized presentation resources in CGSLS, the demand value is dynamically altered according to the user's operation. For a certain type of resource, the demand value increases by 0.1 each time the user views it, that is, the average weight value increases by 0.05; on the contrary, each time the user hides that kind of resource, its average weight value decreases by 0.05. For example, the average weight value of the translation of the second example sentence and the third example sentence in the domain model are 0.42 and 0.63, respectively. Therefore, the translation of the second example sentence is initially hidden and the third example sentence is initially displayed on the learning page. If a learner continuously views the translation of the second sentence twice and hides the third sentence three times, his user model adjusts the average weight value of the translation of the second sentence to 0.52 and the average weight value of the third sentence to 0.48. Consequently, in the next learning session, the learning page will initially display the translation of the second sentence and initially hide the third sentence for this learner.

7 Strategies of Grammar Exercises

There are two types of grammar practice in CGSLS: pre-learning test and post-learning exercise.

Figure 4 shows the interface of the pre-learning test. The format of pre-learning test is dragging the words to make a sentence. The main part of the page exists the image, translation and words. At the bottom, there are tips and buttons for I don't know and Submit. The Exit button is located in the upper left corner, which allows learners to exit the test and learn the target knowledge point or select another knowledge point.

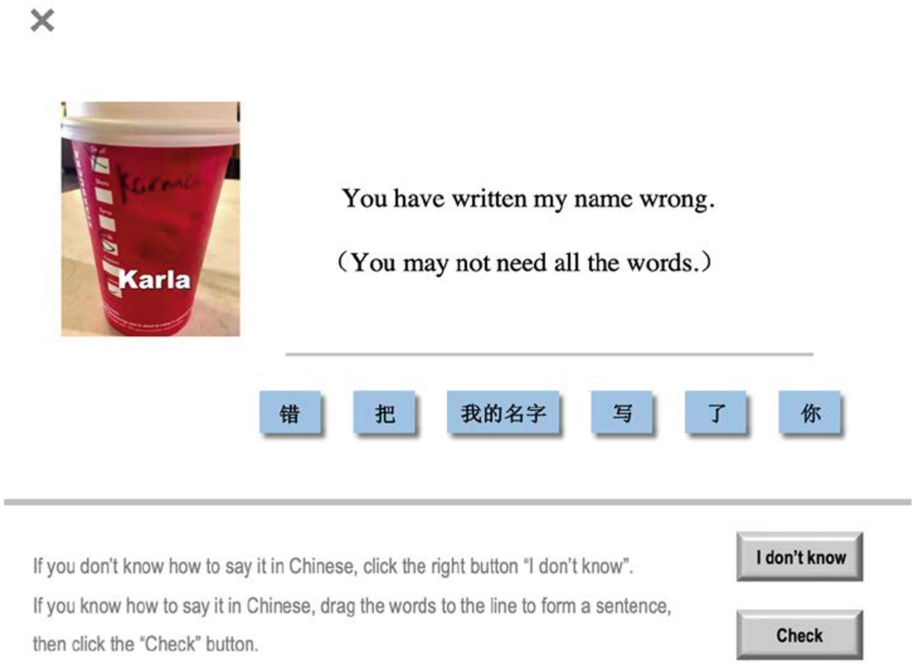

Fig. 4. The pre-leaning test interface.

In most cases, the pre-learning test has five questions. When a learner's accuracy rate is not less than 60%, the system suggests that the learner try a new language point or move straight to the post-learning exercise of that language item to further reinforce it. When a learner's accuracy rate falls below 60%, the system assumes that the learner hasn't mastered the language point and labels the learner as needing to study it. Simultaneously, the system searches the domain model to see if that language point has preceding knowledge, and if so, it will show the pre-learning questions for that preceding knowledge to determine whether the learner is qualified to learn the target grammar item. Similarly, if the learner's correct rate in the test is less than 60%, the learner needs to learn the preceding knowledge first and then learn the target grammar item; if the learner's accuracy rate is greater than 60%, the learner can go to the interface of the target knowledge point directly.

To assist students master grammars in traditional classrooms, teachers would use mechanical exercises and communicative tasks. The former helps students in understanding and memorizing the language point by repeatedly practicing the structure, establishing the link between the form and its meaning. The latter is based on students' mastery of sentence structure and meaning, it focuses on how to properly use the target grammar [9].

There are three kinds of practice in the post-learning part: mechanical, communicative and extended exercises. The difficulty level increases gradually from mechanical to communicative to extended exercises, while within each level, the questions are also arranged in order from easy to difficult due to their format. Mechanical practice has two purposes: first, based on the stimulus-response learning theory, it helps learners remember the structure of newly learned grammar item through repetitive practice [12]; second, based on the acquisition research, it reduces the possibility of internal bias of learners through designed exercises [13]. There are two types of communicative exercises. One is asking learners to decide whether to use the new language points in a certain situation. It focuses on semantic aspects, primarily avoidance and generalization of learning errors [13]. The other one is demanding learners to choose appropriate questions or answers. It aims to practice the language usage in daily life [12]. The extended exercises focus on language points that have association and similarity relationships in the grammar knowledge graph. The system uses multiple-choice questions to help learners recognize the similarities and differences between these language points. Each question in the system reflects a certain attribute of the language point and is labeled in detail, so that CGSLS can analyze the learners' weaknesses based on their performances in the post-learning exercise and push the corresponding questions for personalized training.

8 Conclusion

In CGSLS, the system first finds the suitable target learning grammar based on the results of learners' initial assessment and pre-learning test. Then the learners can determine whether they want to learn that item based on their own needs and interests. They can learn the target grammar by various resources, including explanation texts, instructional videos, and sample sentences. By monitoring learners' performance in the post-learning exercise, the system can evaluate their learning and provide appropriate suggestions as well as additional practice.

In contrast to traditional grammar learning software and MOOC courses, the grammar learning path in CGSLS is not fixed, but is determined by a combination of the grammar difficulty sequence, arrangement pattern and learning condition. The grammar videos aren't merely duplicated from the textbook but designed based on the constructivism theory and classroom teaching research. The videos are also clearly marked for learners to easily locate the part they need. The presentation of grammar resources is also dynamically adjusted according to their influence value and demand value. The grammar exercises are grouped into three categories and presented to learners in order of difficulty. Due to the questions are marked with detailed attributes, the system can make accurate cognitive diagnoses. All of these efforts make the grammar learning in CGSLS consistent with language acquisition and personalized for learners. Therefore, CGSLS can make an effective impact on the grammar learning.

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AI Translation Quality Evaluation of Attributive Clauses Based on Faithfulness, Expressiveness and Elegance Principle

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Abstract. The widespread use of AI translation has made AI translation quality assessment an increasingly important topic, but related researches need deepening. There exist no sufficient studies comparing human translation and AI translation through statistical analysis. This paper compares human translation, Google translation and Youdao translation of attributive clauses. Data analysis of the online questionnaire shows that the quality of human translation is higher than that of AI translation. The quality of Google English-Chinese translation is higher than that of Youdao. Qualitative analysis is under the guidance of "Faithfulness, Expressiveness and Elegance" principle and the BCC corpus. The qualitative analysis results verifies the results above. Compared with Youdao, Google has better control over the translation methods of attributive clauses, even closer to the expression of human translation. Preposition translation, substitution of pronouns for antecedents, repeated antecedents, additional translation methods are used in line with the original text. However, Google translation is not perfect in some aspects and may neglect some Chinese expression habits. Occasional mistranslation of words or neglect of some Chinese idiomatic collocations are found. Sometimes nouns cannot be flexibly translated into verbs according to Chinese language rules in Google translation.

Keywords: AI Machine Translation · attributive clause · Faithfulness, Expressiveness, Elegance

1 Introduction

Since Warren Weaver put forward the concept of computer translation in the 1940s, modern statistical machine translation has been developing continuously. The new generation of neural network translation has made breakthroughs, which not only has semantic understanding, word recognition and reading, image recognition etc., but also makes rapid progress in translation speed. It is expected to break the "Tower of Babel dilemma" caused by the diversity of languages in the world. While the widespread use of artificial

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intelligence translation has made artificial intelligence translation quality assessment an increasingly important topic. Liu Chongdev [1], Zhou Fangzhuv [2] and many other scholars have made clear that English attributive clause is difficult to learn and not easy to translate well. Thus attributive clauses translation quality is one of the most important elements to evaluate the overall translation quality. So the AI translation quality evaluation of the attributive clauses is of certain research value.

This paper takes human translation, Google translation and Youdao translation as the comparative research objects and carries out an online questionnaire survey. Then the online questionnaire data is analyzed to show the quality of attributive clause translation between artificial translation and human translation. Afterwards, based on the famous Chinese translator Yan Fu's translation principle "Faithfulness, Expressiveness and Elegance", a qualitative analysis is carried out on the sentences with the highest and lowest scores in Google Translation and Youdao Translation. This paper aims to provide ideas for machine translation designers to help them design AI translation software with better translation quality.

2 Faithfulness, Expressiveness and Elegance Principle

According to the language habits (i.e. Chinese expression habits) of the target language country (China), this paper selects Yan Fu's principle "Faithfulness, Expressiveness and Elegance" for qualitative analysis, and strives to take into account the accessibility, fluency and readability of the translation when evaluating. Meanwhile the principle is used to see if the translation can meet with the readers' readability and aesthetic appreciation in the target language country (China).

Yan Fu's translation principle "Faithfulness, Expressiveness and Elegance" which is put forward based on his own translation practice experience absorbs the ancient Buddhist translation thoughts. This translation principle can be said to represent the highest standard of traditional Chinese translation theory. In 1898, Yan Fu said in Tian Yan Lun (his translation of Evolution and Ethics and other Essays): "there are three difficulties in translation: faithfulness, expressiveness and elegance."

"Faithfulness" means that the translation does not contradict the original text, namely, the translation should be accurate, no deviation, no omission, and no addition or deletion at will. Being faithful to the original text mainly means being faithful to the rules and forms of language expression of the original text. "Expressiveness" means not sticking to the form of the original text totally, and the translation should be smooth and clear. "Elegance" means that the words used in the translation should be appropriate, and pursue the classic elegance of the article itself, and that the translation has literary grace. Nowadays, the word "Elegance" strives to make the language elegant and avoid the dullness of the translation on the basis of the Faithfulness and Expressiveness. "Faithfulness, Expressiveness and Elegance" is not a static theoretical system, but an open and inclusive dynamic theoretical system with diversified characteristics. It is a common criterion in China for the translation quality evaluation and reflects translation's nature of regularity and flexibility.

In translation, the most basic thing is to correctly convey the meaning of the original text. Based on the structural differences between English and Chinese attributives, in order to achieve “Faithfulness”, it is necessary to analyze the linguistic elements that play the same role in the target language, and then put the words, phrases or sentences that can play the same role in the appropriate positions. The Chinese elements that play the same role as attributive clauses include prepositional attributives, simple sentences, coordinate clauses and adverbial clauses in Chinese [3]. To reproduce the information expressed in attributive clauses, we should adopt the expressions that conform to the translation habits in the target language.

In Chinese, parataxis and internal connection is emphasized, and relatively formal connection is not emphasized [4]. While in English, hypotaxis is emphasized, and formal standardization is emphasized as well. In the process of translation, complete equivalence can not be achieved. When the sentence structure is complicated, this equivalence is more difficult to achieve. And then certain word order adjustment is needed. In order to know how English complex sentences with attributive clauses can be better translated into Chinese, we first need to compare the differences of attributives between the two languages.

In English, attributives can be words, phrases, or sentences, which can be placed in front of or behind the modified words. The attributive clause is placed after the modified word and is guided by relative pronouns or adverbs [5]. While the attributive in Chinese is placed in front of the modified word and connected by “的”. It can be expressed as:

- English: Antecedent (modified word) + Relative pronoun/Relative adverb + Attributive clause
- Chinese: Attributive + de (Chinese “的”) + Modified word

Therefore, in the English-Chinese translation of attributive clause, the most direct way is to put “的” in front of the antecedent (modified word). But because the attributive clause appears in the pattern of a sentence, which is longer than a simple word or phrase as an attributive, so when the attributive clause is short, we can use the “preposition” translation method to convert it directly (put “的” in front of the antecedent). If the clause is long, we can repeat the antecedent or use pronoun to replace the antecedent. In addition, it should be noted that attributive clause can be divided into two types: restrictive attributive clause and non restrictive attributive clause, and they also have strong or weak restrictive and modifying effects on antecedents. In particular, some non restrictive attributive clauses have actually weakened their function of limiting and modifying the antecedent or the main sentence from the semantic or pragmatic function, although they seem to be attributive clauses from the surface structure. And they logically have some adverbial relationship with the main sentence [6]. We should also pay attention to this phenomenon in the translation process. In the translation of attributive clauses, we should get rid of the restriction of the grammatical structure of the original English text, accurately grasp its logical relations and semantics, flexibly adapt sentence patterns. We need to make the translation conform to the Chinese norms on the basis of transmitting the original information so as to ensure the faithfulness and smoothness of the translation [7].

“Expressiveness” and “Faithfulness” complement each other. Just due to the complexity of attributive clause structure, the fluency and readability of the translation will face more challenge after some adjustments to the original text. The translation should be easily accepted by Chinese readers.

Chinese traditional culture attaches great importance to "elegance", which is also true when it comes to words. Ancient Chinese poetry is evidence for their pursuit of "beauty" in words. In this way, it is particularly important to treat long complex sentences with attributive clauses into aesthetic appreciation in line with Chinese expression habits.

Thus, it can be seen that if we want to study the English-Chinese translation, we need to meet the reception ability and aesthetic requirements of the target country. This theoretical standard (Faithfulness, Expressiveness and Elegance) will play a good guiding role in the analysis of the English-Chinese translation of attributive clauses. Therefore, this study chooses Yan Fu's "Faithfulness, Expressiveness and Elegance" to make a qualitative analysis according to the language habits of the target language country (China).

3 Quality Evaluation Design for E-C AI Translation of Attributive Clauses

To evaluate the performance of the new generation of neural network translation in the English-Chinese translation of attributive clauses and find out the possible problems, as well to select one with higher accuracy from the two main translation tools (Google and Youdao), this paper intends to discuss through empirical data. Forty complex sentences with attributive clauses and their corresponding Chinese translation (including restrictive attributive clauses and non restrictive attributive clauses) are extracted from the corpus. These forty original English sentences are input into Google online translation and Youdao online translation respectively to get the corresponding 80 Chinese translations. Then each original sentence has tree translations containing human translation, Google translation and Youdao translation. The source of the translations is not marked in the questionnaire. And all the questionnaires were distributed in the form of online questionnaire (Online questionnaire link: https://www.wjx.cn/vm/Ou9wJrS.aspx or see the appendix at the end of the paper). These online questionnaires were distributed to college students (English majors and non English majors, not limited to grade), social workers with translation needs (such as English teachers, foreign trade company workers, etc.), aged between 18 and 35, who are not strictly required to have translation experience. Participants were asked to rank the three translations of each sentence. The best translation was marked "1" and the worst "3".

4 Data Processing and Analysis

4.1 Quantitative Analysis

After the released questionnaires were collected, their data needs to be processed. The sorted translations of the received online questionnaire were scored. (with the order of "1", that is, "3" points for the best translation; "1" for the worst translation, that is, "1" point and "2" points for the medium translation.) A total of 50 questionnaires were

Table 1. Data Description of Each Translation.

	Human Translation	Google Translate	Youdao Translation
Questionnaires (copies)	50	50	50
Average Value	109.00	86.59	84.14
Standard Deviation	0.24	0.22	0.21

collected. The scores of human translation, Google translation and Youdao translation are tabulated in Table 1.

By analyzing the data in the table and comparing the three kinds of translation, we know that from the average value, the overall quality and acceptability of the human translation are the highest, and the Google translation is better in the two AI Machine Translation; seen from the standard deviation, the acceptability dispersion of the Youdao translation is the least obvious, while the acceptability dispersion of the Google translation is higher than that of the Youdao translation. That means some of Google translations' acceptability is very high, and some may be low. Generally speaking, Google translation's quality is higher than that of Youdao. Where are the differences lying in? We will discuss through qualitative analysis.

4.2 Qualitative Analysis

In order to answer why the quality of human translation is higher than that of AI machine translation, and why the acceptability of Google translation is higher than that of Youdao translation, this paper will make a qualitative analysis. Meanwhile, we also try to see the potential problems from the performance of the new generation neural network Machine Translation in E-C translation of attributive clauses. Additionally, this paper tends to help the majority of E-C translation demanders faced with the coming era of AI Translation paid service to choose from the two translation tools (Google, Youdao) the better one. And we hope that an AI Translation tool with higher accuracy and close to the standard of "Faithfulness, Expressiveness and Elegance" will be selected for users. The paper will separately analyze five sentences with the highest score and five sentences with the lowest score taken from Google.

Five Google translations with the highest scores:

Example 1 One incident that provided the basis of an important shift in Josie's thinking occurred at lunchtime.

Translation:

Artificial: 在一次午餐的时候发生了一件事，这件事为乔西思想的重大转变提供了基础。（average score 2.26, Only scores are shown in the following text）

Google:在午餐时间发生了一起为乔西的思想转变提供重要依据的事件。（1.94）

Youdao:有一件事发生在午餐时间，它为乔西思想的重要转变提供了基础。（1.38）

Among the three translations, the human translation gets the highest score. Comparing human translation and Google translation, there are two points worth noting:

- First, because the attributive clause of the sentence is too long (the modifier is too long), so it is easy to lead to sentence imbalance if we use the "preposition" translation method.
- Second, the attributive clause "important" modifies "shift" rather than "basis", which should be translated as "思想上的重大转变".

The Google translation deviates slightly from the original meaning and is not faithful to the original. Google translation does not stick to "Faithfulness". But why its score is not the lowest compared with human translation and Youdao translation? Because in the daily use of Chinese, "提供重要依据" is very common, which caused some subjective misleading to the interviewees. Compared with human translation and Google translation, Youdao translation translates "important shift" as "重要转变". Is "重大转变" or "重要转变" more suitable for Chinese expression? From the BCC corpus of Beijing Language and Culture University, we found the answer—the frequency of "重要转变" is 90, and that of "重大转变" is 476 [8]. In addition to the translation of attributive clauses, the word order of the first half sentence of Youdao translation should be adjusted. In Chinese, time adverbials are used to be placed in the middle of the sentence or at the beginning of the sentence (before the subject) to achieve the "Expressiveness" of the sentence [9]. On the whole, human translation is far better than Google translation and Youdao translation, and Google translation is better than Youdao translation.

Example 2 The amount of water which is required for irrigation depends on many factors.

Translation:

Artificial: 灌溉所需的用水量由许多因素决定。（average score 1.9）

Google: 灌溉所需的水量取决于许多因素。（average score 2.26）

Youdao: 灌溉所需的水量取决于很多因素。（average score 1.42）

All the three translations achieve "Faithfulness". Because the attributive clause in this sentence is relatively short, it can be directly transformed according to the English and Chinese attributive structure—English: Antecedent (modified word) + Relationship between word + Attributive clause; Chinese: Attributive + 的 + Modified word. Add "的" after "灌溉所需" and put it before the modified noun "the amount of water". This word order adjustment takes into account the fluency of Chinese expression. Although these three translations translate attributive clauses in that way, Google translation gets the highest score, even higher than human translation. The reason is that Google translation "取决于" is more concise and accurate than human translation "由......决定". Both Google and Youdao use "取决于". But the difference between them is that Google uses the adjective "许多" instead of "很多" to express a large number. From the choice of "许多" in the human translation, we can see that in the two words "许多" and "很多", Chinese prefer to use "许多" to express large quantity, and "许多" is more acceptable.

And it can be proved from the BCC corpus of Beijing Language and Culture University. The frequency of " 许多" is 335005, and the frequency of " 许多" is 323552.

Example 3 There are many mollusks which live in the sea.

Translation:

Artificial: 有许多生活在海里的软体动物。（1.82）

Google: 海洋中生活着许多软体动物。（2.26）

Youdao: 有许多软体动物生活在海里。(1.5）

This sentence's structure is not complicated, and the meaning conveyed is also easy to understand, so it is not difficult to realize "Faithfulness". The original sentence is a attributive clause with "there be". When translating the sentence into Chinese, the artificial translation uses the same method of "preposition" as in example 2. Because the predicate of this complex sentence appears in the sentence pattern of "there be", the meaning expressed by the verb "be" is not as vivid as "live", so Google translation sees the predicate of the subordinate sentence "live" as the predicate of the whole Chinese sentence, and the translation is transformed into the structure of "there + intransitive verb". Examples of "there be" structure are as follows:

- There stands a tree in front of the house.

房前有一棵树。

- There remains much to be done.

还有许多事要做。

- There comes the bus.

公共汽车来了。

Google's translation adopts the sentence pattern in line with Chinese habit—"（在）某处有（或用动态动词）某物", so it has higher score and higher acceptability.

The analysis of Google Translation's top three sentences the three sentences shows that Google AI translation is closer to human translation in the control of the attributive clause translation method, and can use preposition translation and pronoun according to the specific situation. It will also adjust the word orders and sentence structures in accordance with Chinese expression habits. However, Google translation is not perfect in some aspects. Occasional mistranslation of some words or neglect of some Chinese idiomatic collocations.

Example 4 These houses are sold at such a low price as people expected.

Translation:

Artificial: 这些房子以人们期望的这样低的价格出售了。(1.68）

Google: 这些房屋以人们期望的低价出售。(2.08）

Youdao: 这些房子以人们预期的低价出售。(1.82）

The three versions all move the attributive clause to the front of the relative pronoun and put the word “的” in front of the modified word “price”. The difference between the three versions of the attributive clause lies in whether the predicate verb “expect” should be translated as “ 预期” or “ 期望”. “Expect” in the Oxford English Dictionary means “ 预期、预计；期待、盼望”. So there is no doubt that it can be translated into “ 预期” and “ 期望”. However, the general public can not control the house price and can only have a kind of expectation mood. In order to convey the original meaning more accurately, it is better to use “ 期望” here. Both human translation and Google translation use the same word “ 期望”, and the difference between these two versions lies in the translation of "a low price". Google translates it into “ 低价”, and human translation is “ 这样低的价格”. Obviously the former is more concise and clear, and is more acceptable to the target language. Therefore, Google translation is slightly better than Youdao translation, and artificial intelligence translation is better than human translation.

Example 5 The most appropriate action will depend on the reason for the relationship problems that your child is experiencing (e.g. termination of friendship, bullying, loneliness).

Translation:

Artificial: 最适当的行为将取决于孩子所经历的关系问题的原因（例如：友谊的结束、欺凌、孤独）。（1.8）

Google: 最适当的行动将取决于孩子所遇到的人际关系问题的原因（例如：终止友谊，欺凌，孤独）。（2.02）

Youdao: 最合适的行动将取决于你的孩子正在经历的关系问题的原因(例如：友谊的终结、欺凌、孤独)。（1.76）

This sentence is longer than the above examples, but the part of the attributive clause is still relatively short. We use “preposition” translation method to put the attributive clause “that your child is experiencing” in front of the antecedent “relationship problems”. All the three translation manage the same. The differences in the scores of the three translations lie in: first, For the translation of "experience", which means “to have a particular situation affect you or happen to you”. Thus translation either “ 遇到” or “ 经历” is acceptable. However, the collocation of “ 遇到” and “ 问题” is more smooth and more in line with the expression habits of the target language (Chinese), so the score of Google translation is high; second, Google translation considers the sentence context and take the translation method of amplification. It adds “ 人际” in front of “the relationship” and translates it into “ 人际关系问题”, which makes the meaning of the translation more complete and easy for readers to accept. So Google translation gets the highest score, even slightly higher than human translation.

Five Google Translations with the Lowest Scores:

Example 6 Eventually, other children avoid interactions with him, which contributes to his annoyance and sense of injustice.

Translation:

Artificial: 最后，其他孩子避免和他互动，这导致他烦恼且感到不公正。(2.06）

Google: 最终，其他孩子避免与他交往，这加剧了他的烦恼和不公正感。(1.92）

Youdao: 最终，其他孩子会避免与他互动，这就增加了他的烦恼和不公平感。(average score 1.6）

This sentence is a complex sentence containing non restrictive attributive clauses. The basic principle of translating this kind of clause should be: make clear whether the antecedent replaced by "which" is a word, phrase or sentence, and make clear the semantics of the main sentence and the clause respectively, and then determine the logical relationship between these two semantic units [10]. The antecedent here replaced by "which" is a sentence. According to the grammatical characteristics of the non restrictive attributive clause, we do not translate the non restrictive attributive clause into the prepositional attribute, but regard it and the antecedent as two semantic units, translate them into two clauses, and translate the relative pronoun into "this" ("这" in Chinese), "this thing" ("这件事" in Chinese) and "this point" ("这一点" in Chinese). This is how the three translations are handled. "Elegance" has higher status than "Faithfulness" and "Expressiveness". The score of Google translation is slightly lower than that of human translation, because the human translation changes the noun into verb when dealing with "his anxiety and sense of injustice". This translation method makes the sentence meaning more vivid, which is in line with the characteristics of Chinese—verbs as the dominant factor. So Google translation is slightly inferior to human translation.

Example 7 They followed a simple plan that involved focusing on specific events that had occurred over the past week, how Josie had left, what she had thought and then the actions that she took.

Translation:

Artificial: 他们遵循了一个简单的计划，计划包括关注过去一周发生的具体事件、乔西的离开方式、想法以及采取的行动。(1.8）

Google: 他们遵循一个简单的计划，其中包括关注过去一周发生的特定事件，乔西的离开方式、她的想法以及所采取的行动。(1.9）

Youdao: 他们遵循了一个简单的计划，包括关注过去一周发生的具体事件，乔西是如何离开的，她的想法以及她采取的行动。(1.88）

The attributive clause of this sentence is long and contains two other attributive clauses—"that had occurred over the past week" and "that she took". Therefore, in dealing with this type of complex complex sentences, in order to ensure the smooth translation and structural balance, the whole attributive clause generally does not use the "preposition" translation method, but uses the postposition translation method. It can be translated by repeating the antecedent "plan" or use pronoun to replace the antecedent. The other two attributive clauses "that had occurred over the past week" and "that she took" are relatively short and can be applied to preposition translation method. Although the score of the Google translation for this sentence is low among the 40 examples, it is the highest among the three translations of this sentence. It can be seen that AI translation (Google translator) has great research value. The advantage of Google translation is that the human translation repeats the antecedent "plan", which is translated as " 计划", and the Google translation is translated as " 其中". On the basis of accurately expressing the original text, Google translation is even more concise than the human translation, which also conforms to the habit of Chinese expression, and has higher acceptability. Secondly, "specific events that had occurred over the past week, how Josie had left, what she had thought and then the actions that she took" after "involved" in the original text is a coordinate structure connected by "and". And both Google translation and human translation well restores the coordinate structure characteristics of the original sentence.

Example 8 Friendships get more stable as children grow older, partly due to improved ability to understand the perspectives of others, which is associated with better skills of conflict resolution.

Translation:

Artificial: 随着孩子的长大，他们的友谊变得更加稳固，部分原因是孩子理解他人观点的能力提高了，该能力可以更好地解决冲突。(2.26）

Google: 随着孩子的长大，友谊变得更加稳定，部分原因是人们了解他人观点的能力提高，这与解决冲突的技巧提高有关。(1.66）

Youdao: 随着孩子年龄的增长，友谊变得更加稳定，部分原因是理解他人观点的能力提高了，这与更好地解决冲突的技能有关。(1.66）

Here "which" refers to the antecedent "ability", so it is easy to produce ambiguity when it is directly translated into the pronoun "this". The human translation repeats the antecedent and points out the antecedent directly to ensure "Faithfulness" and accurately conveys the meaning of the original sentence. However, both Google translation and Youdao translation are translated as " 这", which does not show the grammatical characteristics of the non restrictive attributive clause here (referring to the preceding antecedent rather than the sentence). Secondly, Google translation translates attributive clauses literally. The noun is literally translated into a noun. While in the human translation it is translated into a verb to make the translation more flexible and smooth. Why is human translation using verbalization more popular with Chinese readers? There are two reasons:

- First, because of the differences between English and Chinese expression habits, Chinese is used to expressing with verbs.
- Second, "which" refers to the antecedent "ability" and it's located in the proceeding sentence "improved ability". "improved ability" is verbalized. In fact, "which" in the attributive clause also refers to "ability". In order to reflect the close structural relationship between the main clause and the subordinate clause, and also for the sake of "Elegance", the subordinate clause should be verbalized just like the main sentence. As a result, the Google translation is be inferior and scores lower after comparison.

Example 9 Teasing is common and is often a way that children demonstrate friendship and familiarity.

Translation:

Artificial: 调侃是司空见惯的事，它通常是孩子们表现友谊和熟悉的一种方式。（2.44）

Google:戏弄很普遍，通常是孩子表现出友谊和熟悉的一种方式。（1.77）

Youdao: 戏弄是很常见的，也是孩子们表示友谊和熟悉的一种方式。（1.44）

The attributive clause "that children demonstrate friendship and familiarity" modifies the antecedent "way". The three versions all adopt the "preposition" translation method, which translates the attributive clause directly and puts " 的" in front of the antecedent. When dealing with the attributive clause, Google translation is almost the same as human translation, but the pronoun " 它" is added to the human translation to refer to "teasing" in the previous main sentence, making the translation more accurate. Human translation is higher than artificial intelligence translation. What are the shortcomings of AI translation? Besides the attributive clause, let's look at the translation of the main sentence. "Tease" means "to laugh at sb. and make jokes about them, either in a friendly way or in order to annoy or embarrass them.". " 调侃" means "to tease with words" and " 戏弄" can also refer to "tease with actions". While the original sentence only needs to express banter at the level of words, so the human translation of " 调侃" is better. In addition, the idiom " 司空见惯" is used in the human translation, reflecting the traditional Chinese language culture and is more acceptable in the target language.

Example 10 One is that the men who made the revolution were practical men.

Translation:

Artificial: 最初发动这场革命的人都是实干家。(2.58）

Google: 一是革命的人是务实的人。(1.78)

Youdao: 一是发动革命的人都是实际的人。(1.22)

In this sentence, the attributive clause part "who made the revolution" can be translated directly and be put in front of the antecedent. The three translations all adopt the "preposition" translation when dealing with this part. However, Google translation omits the translation of the verb “made” and translates directly into “ 革命的人”. Such omission makes the translation deviate in conveying the meaning of the original sentence, and fails to be “faithful to the original text”. The original sentence intends to express a man who “launch the revolution”, so it is not accurate to say only “ 革命”. To say “ 革命” alone can also mean “participate in revolution”. This is one of the reasons why Google translation scores lower than human translation. Second, as for the translation of “practical men”, the human translation is “ 实干家”, the Google translation is “ 务实的人”, and the Youdao translation is “ 实际的人”. Both the human translation and the Google translation are “ 务实” in their understanding of “practical”, and it is accurate. “ 实际的” is generally used to describe things. However, compared with Google translation, human translation is more popular, although there is no great difference between “ 务实的人” and “ 实干家” in the sense. For example, in Chinese, we say “ 画家” in stead of “ 画画的人”, and “ 歌唱家” in stead of “ 唱歌的人”. Similarly, “ 务实的人” is called “ 实干家” conventionally in Chinese.

When translating long attributive clauses or complex sentences containing attributive clauses, Google sometimes does not recognize the location of the antecedents accurately. Additionally, when translating nouns, it can not flexibly translate them into verbs according to Chinese language rules, and even sometimes it directly omits the translation of verbs. Therefore, if the sentence is more complex, translator needs to do post editing. For literary texts that need to consider the specific use of words, the post editing work will be more complicated. Google translator is a good helper for simple daily translation activities.

5 Conclusion

From the quantitative results of this study, we can see that:

- In terms of acceptability, there is a significant difference between the Chinese translation of attributive clauses of Google translation and human translation; between the two AI translation tools Google is better.
- The acceptability of AI machine translation varies greatly. Some is even close to an artificial one, and some seriously affects the understanding of the original text. Although the overall score of Google translation is higher than that of Youdao Translation, the difference in acceptability is larger than that of Youdao Translation.

The results of qualitative analysis show that machine translation do well in recognizing English clauses and processing complex sentences containing simple attributive clauses. On the premise of accurately conveying the meaning of the original text, certain word order adjustment can be made to make the translation more concise and more in line with the expression habits of Chinese. It can carry out certain logical arrangement in the process of translation, and even better reflect the adverbial function of attributive clauses in the translation. In the process of translation, it is possible to make the conventional conversion from “English: Antecedent (modified word) + Relationship between word + Attributive clause; Chinese: Attributive + de (Chinese “ 的”) + Modified word”, as well as some unconventional conversion (addition/omission). However, the AI translation system is not stable. When translating long attributive clauses, complex sentences or "multiple nouns + relative words", the antecedent can not be accurately positioned. The Chinese habit of dynamic expression (verb-preferred) is sometimes ignored. Although the overall score of Youdao translation is lower than Google translation, the system is relatively stable.

Based on the above analysis, this study provides suggestions for paid AI translation in the future. It is hoped to provide ideas for AI machine translation designers to design AI translation software with better translation quality. When AI translation services come in the future, users will be able to choose an AI translation tool suitable for text features more quickly. A comprehensive comparison between Google translator and Youdao Translator shows that the overall quality of Google translation is higher with more accuracy. Sometimes there are mistakes in the translation, but it does not affect the understanding of the main idea of the original text. If the sentence is complex, the translator needs to do post-translation editing after using Google. For literary texts whose words need to be considered carefully, the work of post-translation editing may be more complicated.

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Reform of Blended-Teaching Mode for Discipline English Based on Mobile Terminal

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Abstract. In the context of the era of big data, the rise of using mobile terminal is also putting forward new requirements for the teaching of Discipline English. Based on some general problems in the teaching practice of this course, we discuss whether adopting the blended-teaching mode can expand the learning space and time, enrich the learning interaction, and improve the learning efficiency in the context of big data based on mobile terminals. And then improve the quality of teaching and enhance application ability for the Discipline English.

Keywords: Discipline English · Mobile Terminal · Blended-Teaching

1 Introduction

As the Discipline English is becoming more and more important, higher requirements are being raised in some aspects of this course, such as the cultivation of students' ability in an all round way, innovation of classroom teaching patterns and the diversification of teaching methods and so on. These are some problems that the teachers are facing and need to be solved. For example, how to use the big date to analyse the difference between the students and cultivate them according to their own conditions [1], and how to combine inverted classroom with mobile terminals and make the mobile terminal into a good tool for students and teachers [2], how to design blended-teaching mode and the teaching activities and so as to improve the quality of classroom teaching and mobilize the enthusiasm of students [3].

Discipline English is that it uses the English as a tool and takes the practical application of English in the computer as the guide. It aims to improve the application ability of students' professional quality in the English context and also enhance the students' reading ability for professional Discipline English literature and international communication. The Discipline English can lay the foundation for students' personal growth and vocational development in the future. At present, students do not have good command of Discipline English, so the teaching reform of it is of great practical significance.

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2 An Analysis of the Current Situation of Discipline English Course

Because of the characteristics of Discipline English courses and the content is theoretical, students feel difficult and they don't have much interest. The learning process is boring and many students use mobile phone in class. The students' ability is uneven and they are not active in learning. The following problems are easy to find in the teaching process [4]:

- This course is generally regarded as a selective course and many students do not pay much attention to this course. What's more, the English level of the students is different, so the teaching activities can not carry out smoothly.
- Many students major in computer think that they only need to master the ability to read English, so then they ignore the learning and practice of oral English. In the English class, they are unwilling to speak English which results in a poor atmosphere of classroom teaching and interaction.
- Students are easy to lose interest in learning science English, because the style is generally more formal and it contains more theoretical knowledge, professional vocabulary and complex and long sentences which make it boring to read.
- Students major in computer in regular institutions of higher learning don't think Discipline English is so important. The time for this course is unreasonable, because most universities offer Discipline English in the first half of the third academic year and only two class hours a week.
- The Discipline English course still adopts the traditional teaching mode. The content of the course is not updated in time and is mainly based on specialized vocabulary, grammar analysis and long sentence translation which can not meet the learning needs of students in computer major.

It clearly shows the present teaching situation of students and there is a must to discuss a new teaching mode based on the problems. The new teaching mode can improve the quality of teaching, stimulate students interest and motivation in class and enhance the ability to use the Discipline English in a practical way.

3 Teaching Activity Design of Blended-Teaching Teaching Mode

The blended-teaching mode combines the advantages of traditional teaching methods with the advantages of education technology in mobile terminal. It can not only play the leading role of teachers in guiding, enlightening and monitoring in the teaching process, but also can show the students' initiative, enthusiasm and creativity as the main body of the learning process. In the information society, we need to use the terminal equipment reasonably for preview and review [5]. The questionnaire survey on the blended-teaching of Discipline English was conducted based on the computer major students in our university. The results indicate that most students have started to use mobile terminals to learn independently in their daily life.

On the other hand, the content, methods and forms of Discipline English course teaching need to be reconstructed as a whole. The whole process of blended-teaching activities should be carry out with the following points [6]:

3.1 Adjustment of the Course

The Discipline English should be set up in the first year and it continues for three academic years which can extend the time of English learning. Moreover, the Discipline English courses should be synchronized with the setting of professional courses. For example, students will learn Java program design in sophomore year and Discipline English courses can be introduced into Java courses. Because of that, students can adroitly understand the menu, error reporting in program operation and the information of program debugging. What's more, students can teach themselves MSDN or SDN help file. Thus, in one hand, students can feel Discipline English is useful and on the other hand, Discipline English can actively promote the study of professional courses.

3.2 Enrich the Teaching Contents

During The textbook lacks the latest technology information and professional terms, which are more interested to students and closely related to reality. Therefore, the teaching content needs to supplement the words about most cutting-edge technology. At the same time, it is also very necessary to introduce the relevant knowledge of science and technology English, including the characteristics of this kind of English, the composition of specialized vocabulary, commonly used English-Chinese translation methods and skills, as well as Chinese and English abstract writing in graduation thesis, English resume writing, etc.

We can select the English text, Wikipedia pages or related images as a background introduction. Many websites about computer science have video materials related to computer technology and knowledge and these video materials are in good pronunciation, image intuitive theme which are conducive to uplift students' interest in learning. And students can also learn new professional knowledge and technology.

3.3 Instantiation of Teaching Process

We can introduce cutting-edge technology, summit forum, reports of cutting-edge technology conference, etc. We can also set a background and ask students to write their own resume, give them English resume the and English abstract in the graduation thesis written by the previous students. Using these methods above, students can find out the problems and guide them to solve them in time which can greatly mobilize the students' enthusiasm and initiative.

Downloading some practical English software manuals, help file and latest technology product instructions can help the students understand the Discipline English and apply what they have learned to the practical situation. We can also assign relevant homework for students to write an instruction for a certain project based on requirement in English. We can require students to use English software to improve their practical English, such as how to use BIOS, using graphics processing software and office software in English version.

We can improve Discipline English to the daily use of mobile phones, such as switching the operating system of mobile phones to English, changing the language of application to English. Taking the wechat as example, we can use the English version of wechat so that students are more used to the English menu.

3.4 Diversification of Teaching Activities

For a certain theme on English learning, take a group as a unit to make situational dialogue design. What's more, we should set up interaction and discussion to encourage the students to ask questions and have the chance to talk. And then atmosphere of the classroom can be activated and the problem of students' reluctance to speak English can be overcome. We should assign homework after class, ask the students to do group discussion and make the discussion into a presentation. After that every group should appoint a student to do the presentation. Through these methods can fully mobilize the students' learning initiative. We should encourage students to use their extracurricular time to actively consult the corresponding materials.

3.5 Diversification of Teaching Activities

The students are taught in different groups according to their English level. Students with similar English level should be taught together and different teaching plans should be formulated according to their knowledge level. Different level students have different teaching tasks. We can recommend good TV and radio programs about science and popularization of science from foreign countries, useful official accounts in wechat, web pages for English learning, MOOC and the courses on the platform. Combining classroom teaching and extracurricular independent learning practice. This is a new mode of combining classroom teaching and extracurricular independent learning.

4 Teaching Implementation Process

4.1 Preparation Before Class

Analysis of English learning situation: we should know the basic information of students before the Discipline English course, including English level, learning interest, learning motivation, information literacy, the attitude to the blended-teaching mode and so on. We should make clear of the students condition based on questionnaire survey or pre-class test and then make different teaching plans.

Analysis of English learning contents: update the latest learning content in time according to the characteristics of rapid development of Discipline English. According to the teaching objectives of Discipline English courses, they can be divided into three aspects. They are application ability, expansion ability and expression ability. It emphasize that the English should be apply in real life and as a tool. And we should analyze the key points and difficult points according to the course content, and we should divide the blended-learning content into online and offline or the degree of depth.

Analysis of the environment of English learning: learning environment analysis is a crucial link in this model, including basic instruments and interactive learning platform. Basic instruments are mainly mobile terminal and network system facilities. The most commonly used among mobile terminals is smartphones and the penetration rate among students is as high as 100%. And the smart phones are also fully competent for mobile learning. Network system facilities include the multimedia classroom and the full coverage of the campus network. For the design and construction of the interactive learning platform, the current interactive learning platform based on mobile terminals is becoming increasingly mature and stable. We can take Huaihua College as an example, the online learning platform is used to support online teaching, interaction in the classroom (including check-in, lot drawing, voting, testing, discussion and questioning, etc.), build hybrid learning projects, achievement display, big data learning analysis for students' online learning situation and other functions. All of these provide a good technical support for teaching. For the teachers, they should use the interactive teaching platform before class, and set up courses and put up corresponding learning resources. For students, they should be familiar with the use of the platform in advance and make all preparations before class.

4.2 Online Activity Design

Online activities mainly focus on interactive learning platforms. And the students' online tasks are mainly self-study on audio and video, literature reading, topic discussion, online testing, questions on difficult problems, group cooperation and submitting reports. Offline activities are mainly based on classroom teaching.

In the online activity, students log in to the learning platform through the intelligent mobile terminal to participate in the learning and discussion and in the form of group cooperation. Finally, they should submit the report. The main tasks of teachers are as follows:

- Announcement: including informing the key points of the new content, teaching objectives and the lists of learning task, making discussion topics, assigning extracurricular reading links, etc.
- Online Q & A: get the learning difficulties of the students according to the online tests and their questions so that the teachers can better make the offline tutoring content.
- Expand the Learning Resources: the teachers should make micro-class in advance, provide audio and video materials related to the theme of teaching content. Both of micro-class and materials can help students to learn indefinitely before class. What's more, they can activate students' learning interest, increase their language input, reduce anxiety. And we can set up interactions to test students' learning.
- Homework comments: the teachers can comment on homework and show the good homework. And the students who have done their homework well will be rewarded and become a learning model in the class.
- Summary and Analysis: The teachers should supervise the forum of the interactive platform and know the online learning of students according to the big data analysis of the platform. And teachers can conduct accurate and personalized guidance to the students.

4.3 Offline Activity Design

Offline activity design is mainly task-setting-oriented and based on classroom learning.

Knowledge teaching: Aimed at the online learning confusion, the teachers should have face-to-face teaching of the key points and difficult points in class, including the grammar and sentence patterns, analyzing the structure of long and difficult sentences.

Assignment: we should set learning tasks each class, including self-study in MSDN, English abstract, resume writing, situational dialogue performing. The purpose is to make a real language and learning situation and to impel the students to get learning outcome. The homework submission can be in various forms such as Word documents, PPT files, pictures, audio, and video.

Discussion organizing and comments: the teachers can organize students to use the mobile terminal to get into the platform to have a discussion and set up some relevant tasks. Students' statements can be on the big screen and they can also give a like to each other. This can make a harmonious classroom atmosphere, increase interactivity, improve their English writing ability. What's more, the students can be attached great importance. For the homework, the teachers can make brief comments and appraise.

Personalized tutoring: We can use the results of analysis from big data platform. The students are differed widely in listening, speaking, reading and writing. Individual tutoring is needed according to students' shortcomings. The teachers can establish contact with students through mobile terminals and they can recommend appropriate web pages, official accounts, video materials and other things for targeted learning.

Class learning and platform test: students can participate in the tests on platform with the mobile terminal. The purpose is to increase interaction, participation and fun in learning. And the teachers can check the students' mastery of specialized English knowledge. For the result of the test, teachers can put it on to the big screen. With that, it can promote self-discipline of the students while in a good learning atmosphere.

Group cooperation and results reporting: This process mainly includes division of labor, literature searching, content organization of the report, PPT making and presentation. In the process of finishing the task, the group members should cooperate with each other. The students can reach for questions in cooperation and in solving the problems they can improve oral communication, the ability of team cooperation and innovative thinking. And then the scenario simulation and presentation can strengthen the ability of organizing, team working, science and technology literature retrieving, knowledge condensing and English expressing. The results of the discussion were made into a presentation and a student should go to the front to state it. The PPT report is a very good preview exercise for future interviews, lectures, and teamwork at work.

5 The Reform of the Learning Evaluation System

Learning evaluation design is an important guarantee to realize effective teaching. The teachers should pay attention to classroom performance of the students. And the homework forms should be more diversified. And these should be apply in the whole teaching process. The way of evaluation is divided into two parts. One is performance at ordinary times (50%) and the other is final evaluation (50%). In the teaching process, in addition to the learning on the online platform, students must also complete the learning tasks assigned by the mobile terminal in the class, which are included in the performance at ordinary times.

5.1 Application Ability of Special English

The teachers should integrate Discipline English into professional courses. Students can read excerpts of original textbooks, skillfully use English operating system and English app, write the abstract in small thesis and graduation thesis, make an English resume, design English specification in their own, etc.

5.2 Professional English Expanding Ability

The teachers can supplement the most cutting-edge technology documents and video materials in English version and the students should complete the corresponding translation or writing task. We can introduce the report of cutting-edge technology, summit forum, cutting-edge technology conference and the students should submit the writings of their own views. We can recommend TV and radio programs related to good foreign technology and popularization of science. We also can recommend valuable official accounts in Wechat, English learning website, MOOC and the courses on the platform. And the students learn them in extracurricular time.

5.3 Professional English Expression Ability

For a certain theme on English learning, take a group as a unit to make situational dialogue. What's more, we should set up interaction and discussion. And then atmosphere of the classroom can be activated and the problem of students' reluctance to speak English can be overcome. We should assign homework after class, ask the students to do group discussion and make the discussion into a presentation. After that every group should appoint a student to do the presentation.

All the above are the homework that students must finish in the learning process and the completion must be included in the usual performance. With the implementation of this program, students can not be in a burnout in the learning process of the whole semester, and they can not cram for the test or cheat the exam. They can really have a good command of and use Discipline English.

6 Summary

Discipline English course has strong application and it always changing. These characteristics determine the importance of innovation in blended-teaching mode. In order to increase students' independent learning ability, mobile terminals are introduced into classroom teaching. It can make full use of the learning platform and use Information-technology teaching means to promote the teaching reform in the context of big data. In the teaching process, we can use stratified teaching, group teaching and personalized teaching. And in class, we can use pre-class materials, situational environment guidance, mobile equipment. And in the evaluation system, we can set diversified homework and the ways of submission. With the integration of these means, students' learning enthusiasm, initiative and independence are fully stimulated. We will promote the deep integration of English teaching and computer technology and enhance innovative consciousness and practical ability of the students. The students can be cultivated into professionals with international vision.

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Research and Practice About Innovative Experimental Course of Machine Vision Project Development

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Abstract. Aiming to settle the problem of knowledge fragmentation, to improve practical and innovation ability of students, research and practice about the innovative experimental course of machine vision project development based on intelligent hardware are carried out. A project-guided case-driven teaching scheme is designed. Taking the project as leading factor, the knowledge involved in the project is decomposed and the knowledge map is made firstly. Then, summarize the relevant knowledge into several modules, and design several experimental cases for each module to promote students to learn the involved knowledge. Finally, through the positive comprehensive project training, students are driven to construct, integrate and internalize knowledge, and their engineering application and innovation ability are effectively improved. The implementation of the course reveals that the course design is reasonable and the project-guided and case-driven teaching scheme works efficiently.

Keywords: Artificial Intelligence · Innovative Experiment · Machine Vision · Intelligent Hardware · Project-guided Case-based Teaching

1 Introduction

Machine vision is an important branch of artificial intelligence, it is also one of the key technologies to realize industrial automation and intelligence [1]. Training college students with capabilities of machine vision project development will definitely promote the development of artificial intelligence industry. Machine vision involves knowledge in several different professional fields such as image processing, mechanical design, motion control. Most current existing teaching is mainly based on ‘lecture and general questions’ of separate knowledge, they emphasize on the theoretical education and neglect the practical education [2, 3]. Resulting that it is difficult for students to transform theoretical knowledge into practical ability. Project-guided teaching, aiming at the comprehensive application of knowledge, can internalize knowledge into students’ professional skills and promote innovation ability through project training [4–6]. Relying on Guangdong Provincial Experimental Teaching Demonstration Centre, this paper mainly introduces

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the innovative experimental course of machine vision project development based on intelligent hardware. The course adopted a project-guided and case-driven teaching method, made scientific design of teaching and experiment, achieved deep integration of learning process and practical activities. It has effectively improved students' engineering application and innovation ability, and achieved good teaching results.

2 Teaching Plan

The innovative experimental course of machine vision based on intelligent hardware adopted a project-guided and case-driven teaching method, as shown in Fig. 1.

The project was token as the leading factor, by decomposing the knowledge involved in the project reverse, A knowledge map was built, then divide and summarize the knowledge into several interrelated modules, and then design several typical experimental cases in each module. The typical experimental cases can effectively drive students to learn the relevant knowledge. Finally, the design and production of object classification devices project competition is organized. Students participate in the whole project process. Through the positive comprehensive training of the project, students are driven to construct, integrate and internalize knowledge, and effectively improve their engineering application and innovation ability.

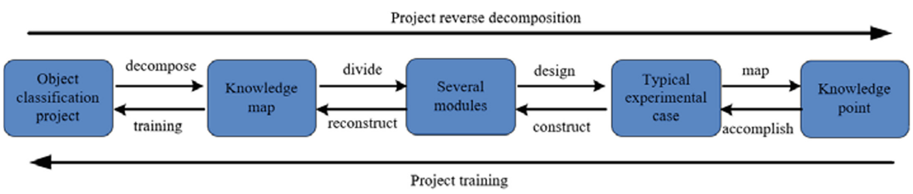

Fig. 1. Project-guided and case-driven teaching plan.

3 Teaching Content Design

The course focuses on object classification projects based on machine vision. Through decomposing the project knowledge map, the course is divided into several modules which are related and independent to each other, as shown in Fig. 2. Since the course is primarily aimed at students major in mechanical and automation, who have foundation in structure design and production, four modules are mainly introduced, they are machine vision system, intelligent hardware, common image processing methods, and image classification based on deep learning. Several typical experiment cases are designed for each module to guide and drive students to learn the relevant knowledge. Finally, the design and production of object classification devices project competition is organized. Students participate in the whole project process including analysis, design and production, debugging and optimization in small groups, which can effectively improve engineering application and innovation ability.

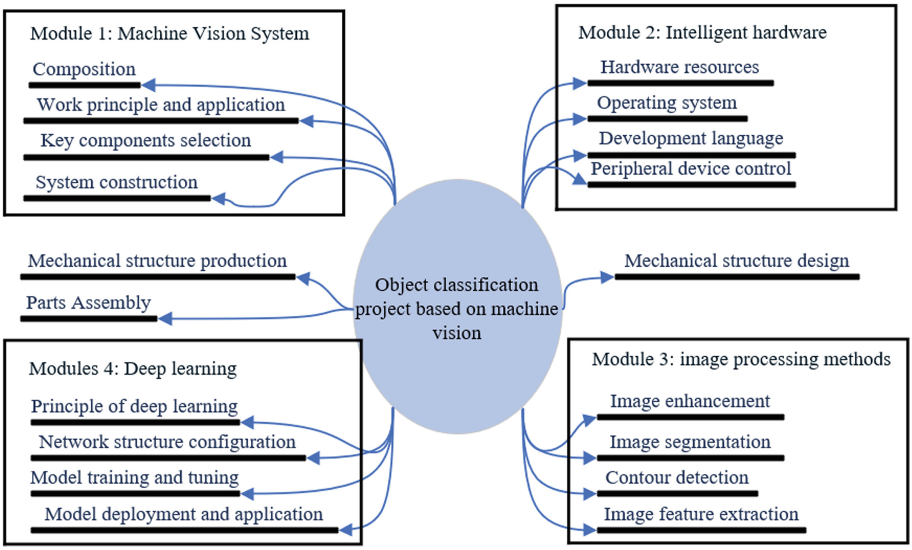

Fig. 2. Division of the project knowledge map.

3.1 Machine Vision System

The composition, theory and application of machine vision system are introduced in this module, and selection precautions of the key components of machine vision, such as cameras, lenses, and light, are also involved. Firstly, students are leaded to visit electronic packaging laboratory, to observe the application of machine vision in automated production equipment such as die bonders, wire bonding machines, glue dispensers. During the process, students are also guided to analyze the selection of machine vision key components. Then, an experimental case of image acquisition based on the machine vision experimental platform is designed. Note that the experimental platform can provide different specifications of light, lenses, and cameras for selection. In the experiment, students need to analyze and select the proper key components for the machine vision system according to the specific detection requirements of specific workpieces, and conduct the machine vision system by themselves to achieve ideal image.

3.2 Intelligent Hardware

Raspberry Pi [7, 8] was chosen as the Intelligent hardware in this course, which can connect a camera to obtain images, have image processing unit to analysis, and have servo control unit to perform operations on the object. Raspberry Pi has been widely used in competitions such as the National College Students' Innovation and Entrepreneurship Training Program, Engineering Practice and Innovation Ability Competition, etc.. Students will be familiar with the operating system and the control method for the peripheral devices through the teaching approach that emphasizes both instruction and practice. Then script writing experiment cases are designed, such as traversing all files with the specified suffix in the folder and saving their paths in the text, driving servo to perform some actions. Considering that students have systematically studied C/C++ language courses, we choose C/C++ as programming language, and python is optional.

3.3 Image Processing Methods

Image processing [9, 10] contains a lot of knowledge such as denoising, enhancement, segmentation, feature extraction. Due to the limited course hours, it is difficult to involve the systematic instruction for image processing in this course. So, case-driven teaching method is adopted. Several experimental cases are designed, such as fruit classification, and handwritten number recognition. Through decomposing the theoretical knowledge required by the case, targeted teaching is carried out. The analysis of practical problems, program design and comprehensive application of image processing are more emphasized.

Herein, we take experimental case of fruit classification for oranges and lemons as an example. Based on the images obtained by button-trigger image acquisition case, the basic concepts of image including pixels, grey levels, regions, contours, and features are introduced. Then, students are guided to analyze the common and different features between oranges and lemons, such as colors and shapes. Then, students need to conduct the image segmentation, contour detection, color recognition, shape feature extraction based on OpenCV by themselves. By comparing the image before and after processing in each process, students will have strong desire to explore the relative knowledge, and on this basis, relevant theoretical knowledge can be explained, which can achieve better effect.

3.4 Image Classification Based on Deep Learning

In this module, deep learning [11–13] theory and model construction and application are incorporated by leading students to realize a small classification task. Students should build up a deep learning environment, download datasets, construct deep learning model, train the model by using high performance workstation GPU, and adjust hyperparameters of the model to get a higher performance. In order to get better understand of the working principle for deep learning, the output of each layer after convolution are visualized in the form of images. In this way, students can better intuitively understand the role of each network layer in deep learning. By using different loss function, activation function, optimizer in different scenario, students can better understand how deep learning works.

Experimental cases such as handwritten digit recognition model construction and fruit classification experiment are designed. In the fruit classification experiment, students collect pictures of various fruits based on button-trigger case, and make necessary image pre-processing, image labeling and generating image datasets. Then, construct a deep learning network model, adjust the loss function, convolution depth and size, the number of fully connected nodes, learning rate, etc., train and test until get an optimal model which should be transferred to Raspberry Pi to conduct the model deployment and application. The specific process of fruit classification experiment is shown in Fig. 3.

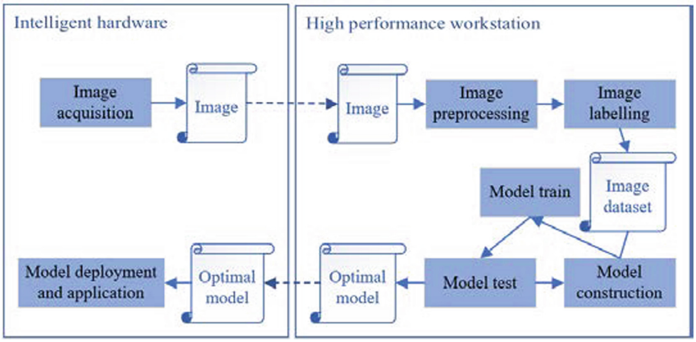

Fig. 3. Experiment process of fruit classification.

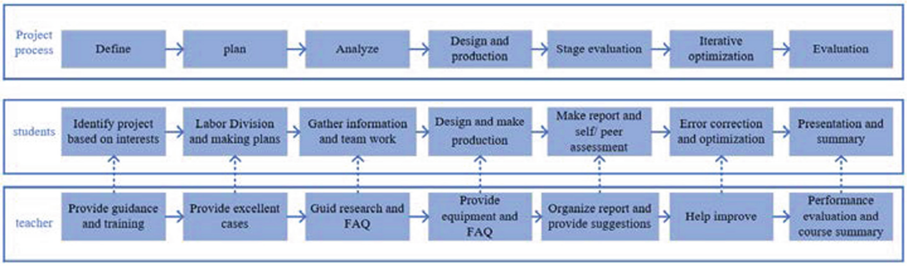

Fig. 4. Project promotion process.

3.5 Object Classification Project

Students work in groups to complete the project of design and production for object classification devices. They should participate in the whole process, including the requirement analysis, design and production, debugging and optimization, etc. During the project process, students need to quickly link to the relevant knowledge learned in section A-D, and conduct efficient knowledge building, integrating and internalizing. Students' ability of engineering application will be significantly improved.

The project progress flow chart is shown in Fig. 4. We encourage 3–4 students of different disciplines or majors to form a team. After the project goals are determined based on students' interests, project plan including the division of labor, schedule, project budget, etc., should be made. Excellent project cases from previous years and necessary equipment for design and production will be provided. After the completion of stage tasks, students should present their works in the form of presentation or report, teachers can make professional evaluation and guidance. Then, students correct deviations, update versions, and optimize their works. This step and the previous step can be repeated according to actual needs. After the project is completed, we organize students to report their work and make a summary, and then output project documentation. At last, the performance evaluation and course summary will be given by teacher.

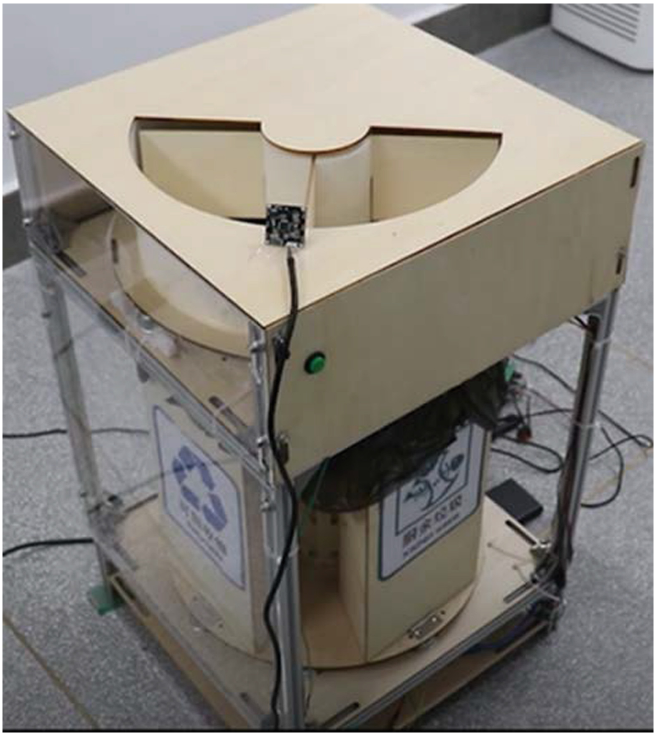

Fig. 5. Garbage sorting device made by students based on the course.

4 Teaching Effectiveness

The course has implemented for years. The course is welcomed by students, the number of students enrolled is one of the highest among similar elective courses. It reveals that the project-guided and case-driven teaching method meets students' innovative needs. By decomposing the project in reverse, a knowledge map is derived. This strategy of exploring knowledge organization can help students to clarify the connections between different concepts. By designing corresponding experimental cases for each module and learning the knowledge points involved in the cases, can help students establish the connection between knowledge and application. From a single experimental task to a comprehensive project, it promotes integrating knowledge into engineering application. Through group work and cooperation, knowledge sharing and linking are stimulated among students with different professional backgrounds. For the problems encountered in the process of project implementation, students are willing to spend more time and energy on thinking, analyzing and solving, which effectively promotes the internalization of knowledge. In addition, the course can lay a good foundation for students to complete graduation design or participate in scientific and technological competitions. Some students have continued to conduct in-depth research, optimize their works or complete new works, and won awards in many national competitions. Figure 5 shows a garbage sorting device made by students based on this innovative experimental course.

5 Conclusion

Aiming to settle the problem of knowledge fragmentation, to improve practical and innovation ability of students, relying on the Guangdong Experimental Teaching Demonstration Center, research and practice about the innovative experimental course of machine vision project development based on intelligent hardware mainly for students majoring in machinery and automation was carried out. A project-guided case-driven teaching scheme is designed, the experimental teaching plan and content are designed, which make deep integration of learning process and practical activities, and effectively improve the students' engineering application and innovative practice ability. The teaching effect proves that the teaching content design is reasonable, and the project-guided case-driven teaching method works efficiently.

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Adaptive Exercise Recommendation Based on Cognitive Level and Collaborative Filtering

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Abstract. Adaptive learning is inseparable from adaptive testing, and adaptive testing needs to rely on students cognitive level for personalized recommendations, and recommending exercises that match students' cognitive level can enhance students' learning interest and efficiency. Some of the existing exercise recommendation methods only recommend based on the similarity between students or exercises, while others only focus on students knowledge level for recommendation. The former ignores students' cognitive level and tends to recommend exercises that are too difficult or too easy. The latter ignores the group nature among students, and the recommendation results are too homogeneous. To tackle these problems, in this work, we propose an adaptive exercise recommendation based on cognitive level and collaborative filtering (ACLCE). Learning students' cognitive level by a deep knowledge tracking model, and then recommends exercises by a neural collaborative filtering algorithm combining students groupness. Extensive experiments on two-real world datasets show the effectiveness of ACLCE by significantly boosting the recommendation. Compared with the advanced baseline method, ACLCE achieves a significant improvement in recommendation effectiveness with the Six to eight percent performance gain.

Keywords: Adaptive learning · Exercise recommendation · Collaborative filtering · Cognitive diagnosi

1 Introduction

At present, the scale of online education has grown by leaps and bounds, which providing students with a large number of videos, exercises and other resources, such as MOOC, NetEase Open Classes, XueTang Online, etc. However, with the increasing scale of educational resources, students are often caught in the dilemma of choosing learning resources [1]. Compared to traditional teaching methods, online learning cannot provide guidance to students in real time and cannot provide personalized learning recommendations [2]. Adaptive learning dynamically presents appropriate learning resources according to students characteristics and needs during the learning process, motivating learners, fostering

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learning autonomy and improving learning efficiency [24]. However, one of the important tasks in understanding students current learning needs is to assess their level of mastery of knowledge in order to better recommend learning resources that match their cognitive level. As a type of educational resource, practice exercises can consolidate students knowledge and guide them in the right direction [22]; Meanwhile, exercise tests can test students knowledge [4], and are widely used in both traditional classroom and online education scenarios. Therefore, how to accurately recommend appropriate exercises for students among the vast amount of exercise resources has become a research topic of interest in adaptive testing [12,36,37].

In recent years, the technology of product recommendation systems has been gradually applied by researchers in exercise recommendation. Scholars regard exercises as commodities in a commercial system and students as users, and use students scores on the exercises as users ratings of the commodities, and students score predictions on the exercises can then be translated into users commodity rating predictions to make recommendations to students [5,26,30,38]. However, exercises are educational resources, and compared to traditional e-commerce recommendations, they have distinctive features that are different from traditional product recommendations. Users have their own learning style in the learning process, their own level of knowledge mastery [4], and their learning paths are different from other users in the learning process. The recommendation of learning resources through similarity does not consider the individual characteristics of learners, and cannot recommend the learning resources that learners really need from their weak knowledge. Therefore, we also need to recommend learning resources that are relevant to the user's own situation.

Educational research has shown that cognitive level has a significant impact on adaptive learning. Knowledge level reflects the extent to which students have mastered knowledge that has evolved over time and cannot be directly observed [6,7]. Adaptive testing requires the design of a cognitive model that can diagnose students' cognitive level, followed by some adaptive selection strategies for adaptive recommendation of students cognitive contextual perception based on their abilities [36]. With the development of deep learning techniques, neural networks to model student answer sequences and thus diagnose students' cognitive level has been proposed, and these methods have achieved significant results [10,13,15,16]. After obtaining the students' cognitive level, how to combine the students cognitive background to make personalized learning recommendations to students. Ye et al. proposed a heterogeneous information network-based learning resource recommendation method, which models students knowledge through Bayesian knowledge tracking and calculate semantic similarity between students and resources for ranking recommendations [9]; Dwivedi provided personalized learning recommendations by think over students study styles and knowledge levels [8]; Zhu et al. proposed combining cognitive diagnostic models with matrix decomposition [11].

Although these methods have been successful in adaptive testing, they also have certain limitations. Specifically, traditional e-commerce-based recommendation methods ignore learners knowledge levels, ignore learners level of knowledge, unable to reflect student's abilites, and do not accurately recommend exercises. Based on knowledge level without considering students and groups of students, it may be more homogeneous in recommending results. The learning effect of adaptive tests is an improvement in doing the questions, rather than simply correcting one item [35]. Therefore, the reinforcement or test exercises recommended to each learner may be less appropriate or inefficient for learning. The question of how to recommend appropriate exercises for students to practice remains a challenging one. We have summarized two problems in this area. Firstly, the level of knowledge of learners is not directly observable and is constantly evolving. Learners mastery of each learning item, i.e. their level of knowledge, is constantly changing during the learning process and cannot be directly observed. The learners level of knowledge affects the percentage of correct answers to questions. Therefore, it is necessary to model the evolutionary knowledge level based on the student's answer sequence. Secondly, capturing other student behaviors during the learning process and groupness between students also has an impact on the recommendation results; for example, students with similar cognitive levels can complement each other strengths in the learning process and consider similarities between students for recommendations.

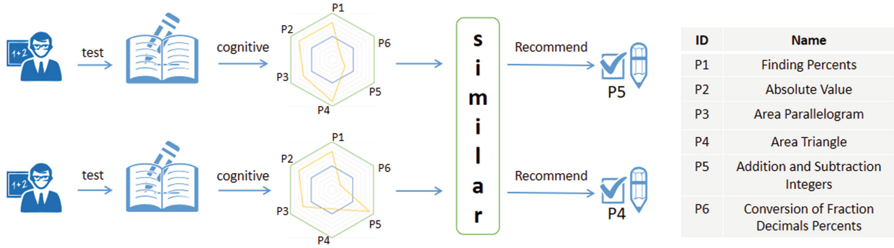

Fig. 1. Collaborative filtering algorithm is used to find users with similar cognitive levels and recommend exercises for them that are adapted to the students current cognitive level

To address these challenges, this paper proposes an Adaptive exercise recommendation based on cognitive level and collaborative filtering (ACLCE), which uses collaborative filtering of cognitive levels to personalize exercise recommendations. Specifically, ACLCE aims to continuously recommend exercises to students Conform to their cognitive level. Firstly, knowledge tracking is introduced to judge the level of mastery using their answer records. The task of knowledge tracking is to automatically track students knowledge level over time based on their historical learning trajectory in order to accurately predict how students will perform in the next step of their learning [4,10,13]. Once the students' cognitive level is obtained, collaborative filtering algorithm is used to find users with similar cognitive levels and recommend exercises for them that are adapted to the students current cognitive level, as shown in Fig. 1. Through the combination of the two, more accurate personalized exercise recommendations can be obtained. The main contributions of this paper are as follows:

1) Firstly, we use the Deep Knowledge Tracking (DKT) method to model the knowledge mastery of individual students, and then use the Neural Collaborative Filtering (NCF) algorithm to obtain students with similar knowledge levels before making recommendations, considering both the individual level and group information of students to improve the reliability of the recommendation results.

2) We demonstrated the effectiveness of ACLCE on two real data sets, achieving 0.786 and 0.551 in HR and NDCG metrics respectively, improving precision of our method by more than Six to eight percent compared to the baseline method.

2 Related Work

2.1 Study of Recommended Methods

Personalized learning resource recommendation techniques mainly include content-based recommendations, collaborative filtering recommendations and hybrid recommendations. In addition, knowledge-based learning recommendation methods are also a hot topic of research.

1) Content-based recommendation is to find the learning resources that best match the learners preferences by comparing the features of the learning resources with the learners preference. Collaborative filtering recommendation in the learning recommendation scenario is based on learners ratings of learning resources to construct a learner-learner matrix or resource-resource matrix, and then find similar learners based on the ratings on resource items [40]. Hybrid learning recommendation methods are methods that combine multiple learning recommendations to achieve improved recommendation accuracy as well as to alleviate problems such as matrix sparsity and cold starts that may occur with single recommendation methods. Renumol correlates the features of learning resources with learners learning style models, calculates the relevance scores of learning resources and learners, and then sorts the recommendations according to the scores [37]. Rosewelt proposes a learning content recommendation method that first extracts the representation features of learning resources, and then classifies the representation features according to learners comprehension levels, so as to identify the exact learning resource content for recommendation in a large amount of data [38]. Content-based learning recommendation methods cannot be separated from learning resource attribute features, and the effectiveness of the method will be greatly reduced once there is a lack of useful feature data. Wang et al. used the Pearson correlation coefficient to calculate the similarity between users and resources in the network, and used the dynamic k-nearest neighbor algorithm to select similar results to push personalized learning resources. WAN et al. propose a hybrid filtering recommendation method that first uses explicit learner modelling methods to enrich learner feature descriptions as much as possible, then applies self-organizing recommendation strategies to cluster learners,

and finally finishes ranking and recommending learning resources by sequential pattern mining [41]. Li Haojun et al. proposed a learning recommendation method based on a multi-objective particle swarm optimization algorithm, which uses learner planning time as a constraint to recommend learning resources with the optimization goal of satisfying both learner preferences and the most appropriate difficulty of learning resources [39].

2) The knowledge-based learning recommendation method considers the knowledge about learners and learning resources in combination and applies it to the recommendation process, recommending resources to students based on their preferences in domain knowledge. Harrathi used ontologies to describe the behaviors exhibited by learners in the learning process, modelling learners, domain knowledge and learning behaviors separately [42]. Knowledge graph-based learning recommendation methods have received attention in recent years. Zhu build a knowledge graph use the emerged knowledge units, target knowledge units, and knowledge unit dependencies in the learning process, which resulted in multiple learning paths, and then recommended learning paths to learners based on their learning record [12]. The main disadvantage of this method is that the requirement for domain knowledge collation is inseparable from human involvement, often with subjective bias, and the completeness of the constructed domain knowledge is difficult to guarantee. In addition, the state of the learner, e.g. affective and knowledge level, is not constant, and the description of knowledge can lead to a solidified learning path if there is no reasonable mechanism for updating it.

2.2 Knowledge Tracking

In 1995, Corbett et al. introduced Bayesian Knowledge Tracing (BKT), which models the learner's latent knowledge as a set of binary variables, each variable representing understanding or non-understanding of a single concept, and using The hidden Markov model iteratively updates the initial probability of each knowledge point to obtain the mastery level of the students [13]. Baker et al. adopted machine learning approach to calculate the probability of student guesses and errors in context, reducing the risk of model degradation [14]; Yudelson et al. introduced the student learning speed parameter into BKT, increasing its accuracy and using it to tutor students in an intelligent tutoring system [15]. Compared to traditional BKT which assumes that once knowledge is mastered it is no longer forgotten, deep knowledge tracking introduces a recurrent neural network model that can model well the behavior of knowledge that will be forgotten if not done for a long time, which is more in line with people perceptions. It is able to model the connections between complex knowledge points and thus discover the intrinsic connections between different knowledge points. Deep Knowledge Tracking (DKT) [16] applies a temporally "deep" flexible recurrent neural network (RNN) to the knowledge tracking task. This family of models uses a large number of artificial "neurons" to represent latent knowledge states and their temporal dynamics, and allows latent variable representations of student knowledge to be learned from data, rather than hard-coding. The cold start problem is solved, and students' knowledge state changes can be dynamically tracked. Unlike the dynamic Hidden Markov Models in education, RNNs have high-dimensional, continuous representations of latent states, richer representations, and they are able to predict subsequent states using the input information.

3 Methodology

We first introduce the ACLCE framework and elaborate on how to use the knowledge tracking (DKT) model to learn students knowledge state level. To explore the recommendation process for students knowledge level, we use neural collaborative filtering (NCF) framework for processing, using multi-layer perceptron to learn between student-exercise interaction functions. Finally, use the collaborative filtering model, which combines the linearity of MF and nonlinear of MLP to model the potential structure of user items and predict the final recommendation results.

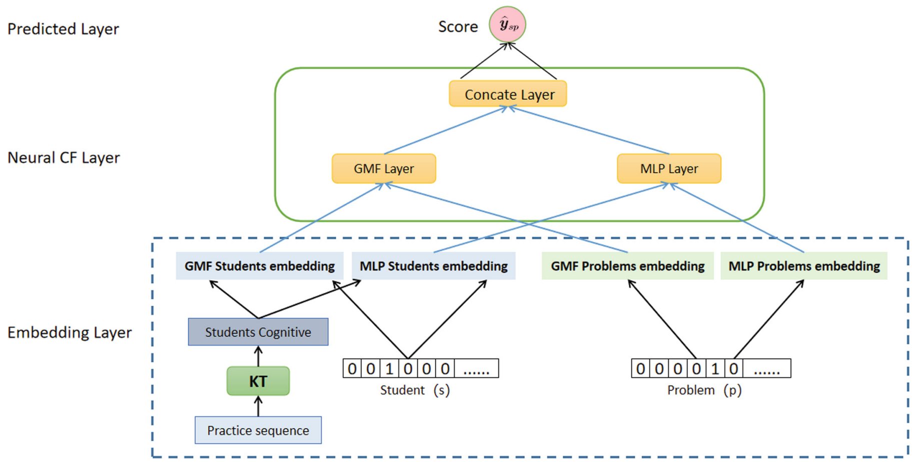

Fig. 2. The overview of our ACLCE framework

3.1 Personalized Approach to Exercise Recommendation Based on Cognitive Diagnosis

Cognitive diagnosis is the goal of personalized exercise recommendation method, which is a learning strategy. It recommends exercises or skills suitable for students according to the calculation of students' cognitive level and their mastery of knowledge points or topics. In the first step, the time series of m students doing exercises $\tau = \{S_1, S_2, ..., S_n\}$, where each student sequence

$S_i = \{S_{i1}, S_{i2}, \ldots, S_{it}\}$ is fed into the recurrent neural network. The t exercises, each exercise is represented by 0,1 respectively as wrong answer or right answer. The corresponding input length is $2t$. The sequence of questions is one-hot encoded and fed into the model. The length of the output sequence y is the total number of questions N, representing the correct answer probability for each corresponding question. Calculate the knowledge level vector for each student. After obtaining the students cognition and combining with the initial embedded representation of students, the final embedded representation of students was obtained. The embedded representation of students and exercises was respectively sent into the NCF framework to obtain the predicted results. The overall framework is shown in Fig. 2.

3.2 A Subsection Sample

Deep Knowledge Tracing: The knowledge level of the learner has a great influence on the next learning plan. However, the level of knowledge of learners is not directly observable and is constantly changing. Using the method of knowledge tracking, the students' implicit knowledge level S_t is obtained from the historical answering records. We adopt the method of Deep Knowledge Tracking (DKT)to model students. Figure 3 is a schematic diagram of the architecture of the module. We assume that each previous learning record $S_t = \{p_t, score_t\}$ has a score of 0 or 1.

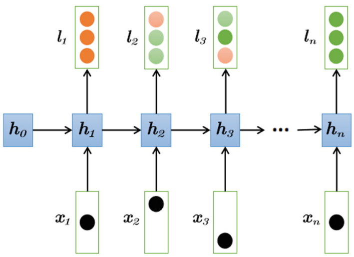

Fig. 3. Illustration of DKT

First, convert a set of learning records S_t into one-hot encoding for vector embedding, and convert the converted embedded representation into a set of low-dimensional representations using formula 1:

$$x_t = S_t W_u \tag{1}$$

Here, $W_u \in \mathbb{R}^{2 \cdot M \times d}$ as the parameters of the embedding layer and $x_t \in \mathbb{R}^d$, where d is the output dimension.

After obtaining the feature representation of students' learning records, the goal of knowledge tracking is to record the students' cognitive level along with the sequence of students answering questions. Then use the RNN or LSTM model described in DKT to map the vectors $x_1, x_2, ..., x_n$ to the output sequence of tacit knowledge level vectors $l_1, l_2, ..., l_n$. Among them, the hidden state h_t updates the state at the moment t as follows:

$$p_t = \sigma\left(\mathrm{W_{xp}x}_t + \mathrm{W}_{hp}h_{t-1} + \mathrm{b}_p\right) \tag{2}$$

$$g_t = \sigma\left(\mathrm{W}_{\mathrm{x}g}\mathrm{x}_t + \mathrm{W}_{hg}h_{t-1} + \mathrm{b}_g\right) \tag{3}$$

$$l_t = \sigma\left(\mathrm{W}_{\mathrm{x}l}\mathrm{x}_t + \mathrm{W}_{hl}h_{t-1} + \mathrm{b}_l\right) \tag{4}$$

$$y_t = g_t y_{t-1} + p_t \tanh\left(\mathrm{W}_{xy}\mathrm{x}_t + \mathrm{W}_{hy}h_{t-1} + \mathrm{b}_y\right) \tag{5}$$

$$h_t = l_t \tanh\left(y_t\right) \tag{6}$$

At the same time, the knowledge level is retrieved from $l_1, l_2, ..., l_n$ using the fully connected layer, Student's cognitive situation is represented by vector $R_t \in \mathbb{R}^M$ as:

$$R_t = \sigma\left(\mathrm{W_{lm}l}_t + \mathrm{b}_m\right) \tag{7}$$

where p, g, l, y are the input gate, forget gate, memory cell, output gate of LSTM respectively. W and b are learned weight matrices and biases.

Overview of Neural Collaborative Filtering: The Neural collaborative filtering (NCF) model uses the DNN network structure to learn the latent feature vector representations of students and exercises separately [21]. In the prediction layer of the model, the learned implicit vectors are mapped to the prediction results through a multilayer perceptron. The model uses MLP to extract high-order feature information to improve the expressive ability of implicit information. The NCF recommendation framework consists of two parts, Generalized Matrix Factorization (GMF) and Multilayer Perceptron (MLP), which learn latent mappings of interaction functions from interaction data. The structure is shown in Fig. 4.

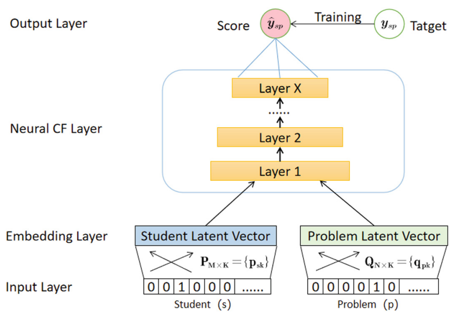

Fig. 4. Illustration of NCF

1) Generalized Matrix Factorization: GMF is called generalized matrix decomposition, where both student and problem are obtained as sparse vectors

by one-hot encoding, and then mapped into student vector and problem vector by an embedding layer. This way, the hidden vectors of student and problem are obtained and used for GMF calculation. This is used for the calculation of GMF. The corresponding output equation is:

$$\widehat{y}_{sp} = \alpha_{out}\Big(\mathrm{h}^T\left((S_{\mathrm{i}} \odot R_i) \odot \mathrm{q}_p\right)\Big) \tag{8}$$

where S_i denotes the student i, R_i denotes the Cognitive Navigation, q_p denotes an exercise, h denotes the Trainable parameter, $\odot$ is Concatenation operation.

2) Multi-Layer Perceptron: MLP is a multilayer neural network, mainly to learn out the MF matrix of high-dimensional hidden vectors, MLP calculation also has a vector vectorization problem, this vector is not the same as the vector in GMF, because the model requirements for the vector are different. Vector construction is completed, based on the multimodal The computational idea is to splice the individual vectors and put them into the DNN to complete the deep learning operation:

$$\begin{aligned} \mathrm{z}_1 = \phi_1\left(S_{\mathrm{i}} \odot R_i, \mathrm{q}_p\right) &= \begin{bmatrix} S_{\mathrm{i}} \odot R_i \\ \mathrm{q}_p \end{bmatrix} \\ \phi_2\left(\mathrm{z}_1\right) &= a_2\left(\mathrm{W}_2^T \mathrm{z}_1 + \mathrm{b}_2\right) \\ &\ldots\ldots \\ \phi_L\left(\mathrm{z}_{L-1}\right) &= a_L\left(\mathrm{W}_L^T \mathrm{z}_{L-1} + \mathrm{b}_L\right) \\ \widehat{y}_{sp} &= \sigma\left(\mathrm{h}^T \phi_L\left(\mathrm{z}_{\mathrm{L}-1}\right)\right) \end{aligned} \tag{9}$$

3) Combining GMF and MLP, the above diagram shows the complete implementation of the approach, with the output layer calculated as:

$$\begin{aligned} \phi^{GMF} &= \left(S_i^M \odot R_i^M\right) \odot \mathrm{q}_p^G \\ \phi^{MLP} &= a_L\left(\mathrm{W}_L^T\left(a_{L-1}\left(\ldots a_2\left(\mathrm{W}_2^T \begin{bmatrix} S_i^M \odot R_i^M \\ \mathrm{q}_p^M \end{bmatrix} + \mathrm{b}_2\right)\ldots\right)\right) + \mathrm{b}_L\right) \\ \widehat{y}_{sp} &= \sigma\left(\mathrm{h}^T \begin{bmatrix} \phi^{GMF} \\ \phi^{MLP} \end{bmatrix}\right) \end{aligned} \tag{10}$$

where W,b and a_x denote the weight matrix, bias vector and activation function of the layer x perceptron, respectively. For the activation function of the MLP layer, we can Rectifier(ReLU).

3.3 Pre-training

In order to understand the model parameters, existing point-by-point methods [18,19] use mainly squared losses for regression.

$$L = \sum_{(s,p)\in\mathcal{Y}\cup\mathcal{Y}-} w_{sp}\left(y_{sp} - \widehat{y}_{sp}\right)^2 \tag{11}$$

where $\mathcal{Y}$ represents the set mastered by students judged by DKT, $\mathcal{Y}-$ represents the uninteracted set, which can be a sample of all interactions that (do wrong) fail to do the topic; and wsp is a hyperparameter that denotes the weights (s, p) of the training instances.

Given the class of properties of implicit feedback, we can consider the value of y_{sp} as label 1, indicating that problem p is relevant to student(s), otherwise 0. To assign such a probabilistic interpretation to NCF, we need to restrict the output y_{sp} to the range [0, 1]:

$$p\left(\mathcal{Y}, \mathcal{Y}- \mid \mathbf{P}, \mathbf{Q}, \Theta_f\right) = -\sum_{(s,p)\in\mathcal{Y}\cup\mathcal{Y}-} y_{sp}\log\widehat{y}_{sp} + \left(1 - y_{sp}\right)\log\left(1 - \widehat{y}_{sp}\right) \quad (12)$$

This is the objective function to be minimized by the ACLCE method, which can be optimized by performing stochastic gradient descent (SGD). Cross entropy loss is used in this paper. By probabilistic processing of NCF, we treat implicit feedback recommendation as a binary classification problem.

4 Experiment

4.1 Introduction to the Data Set

The first data set is the Assistments2009 public data set, a public online education platform that simultaneously teaches and assesses student learning online, and contains over 500,000 submissions of primary school mathematics exercises. The second dataset is a part of the student submission history crawled from a university online programming platform (POJ) with more than 900,000 students, 3,000 questions and 20 million programming submissions (Table 1).

Table 1. Statistical information for the data set

Data sets	Number of students	Number of topics	Number of exercise submissions
Assistments2009	4217	124	525535
Poj	3800	500	82624

4.2 Experimental Environment

The experiments were conducted in the PyCharm IDE on a 64-bit windows 10 system. Based on python environment 3.7 and pyTorch deep learning framework version 1.8.0. Computer cpu is 3.50 ghz intel core i5 7200, memory is 16gb, gpu is GTX1050Ti 4G version.

4.3 Experimental Methods

In this paper, we use the leave-one-out evaluation model commonly used for implicit feedback tasks, and for each test user, the last mastered exercise is selected as the positive example in the test set, and another 107 unmastered exercises are selected as the negative examples in the test. Evaluation metrics are based on many evaluation metrics of the Top N recommendation algorithm. This experiment will use HR, NDCG. HR is calculated as follows:

$$HR = \frac{1}{N}\sum_{i=0}^{N} hit\left(i\right) \tag{13}$$

N denotes the total number of visits by users, that is, the number of users in the real big pile. $hit(i)$: If the recommendation system recommends product i, $hit(i)$ will be 1, otherwise it will be 0.

NDCG is widely used for evaluation tasks in recommendation ranking and information index ranking. The DCG is first introduced and is calculated as follows:

$$DCG_n = \sum_{x=i}^{n} \frac{2^{rel_x - 1}}{\log_2(x+1)} \tag{14}$$

Rel_x is the relevance of the exercises to the students. In this experiment, the correlation is 1 if the recommended exercise is a positive sample and 0 for a negative sample.

The DCG evaluates the recommendation list for one user only, but not all the recommendation lists are the same length for each user, so to compare across all users the data needs to be normalized, NDCG is introduced:

$$NDCG_n@K = \frac{DCG_n@K}{IDCG_n} \tag{15}$$

where the IDCG is the DCG in the idealized state, i.e. the sorting has been completed by relevance size.

To demonstrate the validity and robustness of our framework, we have compared it with the following baseline methodology.

MF: This method uses a matrix decomposition model to consider biased information from students and exercises.

UserCF: User-based collaborative filtering recommendation using student-exercise score matrix, calculating cosine similarity between students to find similar students, then predicting the target student's performance based on similar students' performance, and making recommendations based on the ranking of different exercise prediction scores.

DMF: This model considers explicit interactions and non-preferential implicit feedback as a deep matrix decomposition model with embedded mapped students/exercises.

NCF: For NCF, we only use the student's problem set for the interaction between GMF and MLP.

Table 2. Performance of the model on the Assistments and Poj data sets

Data	Metric	MF	UserCF	DMF	NCF	ACLCE
Assistments 2009	HR	0.632	0.657	0.726	0.734	0.786
	NDCG	0.396	0.402	0.505	0.513	0.551
POJ	HR	0.583	0.625	0.681	0.687	0.721
	NDCG	0.364	0.394	0.484	0.496	0.523

Table 3. Improved knowledge tracking effects introduced

Assistments 2009	DKT+MF	DKT+CF	DKT+DMF	ACLCE
HR@10	0.661	0.711	0.759	0.786
Improve	4.59%	8.22%	4.45%	7.08%
NDCG@10	0.420	0.428	0.537	0.551
Improve	6.06%	6.48%	6.33%	7.41%

4.4 Analysis of Experimental Results

Table 2 shows the top 10 performance. According to the results, ACLCE can significantly improve the recommendation performance. This performance gap can be attributed to effective modeling of individual students' cognitive levels to achieve customized user/project representations under recommendation goals.

We also embedded the cognitive level representation for the baseline algorithm in Table 2. As shown in Table 3, compared with the traditional baseline recommendation method, the performance of the recommendation method that introduced students knowledge level was improved to a certain extent, with an average increase of over 7%, compared with only considering the interaction between students and questions. It is effective to introduce students' cognitive level to recommend exercises to students.

Figure 5 shows the performance of top k recommendation list. The value of k ranges from 1–40. With the increase of k, both HR and NDCG increase. Experiments show that the multi-layer neural structure of neural network can learn more implicit interactive information from students' cognition and questions.

For the three modules in the NCF algorithm, we carry out the influence of different modules on the recommendation effect. As show in Fig. 6. GMF module adopts simple linear fitting, the basic principle is similar to MF algorithm, so the performance of single GMF module is similar to that of DKT+MF. MLP uses four-layer neural network structure to deal with the relationship between students, cognition and questions, so it has a great improvement in performance.

4.5 Discussion of Results

From the above experimental results, it can be seen that the adaptive exercise recommendation method based on students cognitive level proposed in this

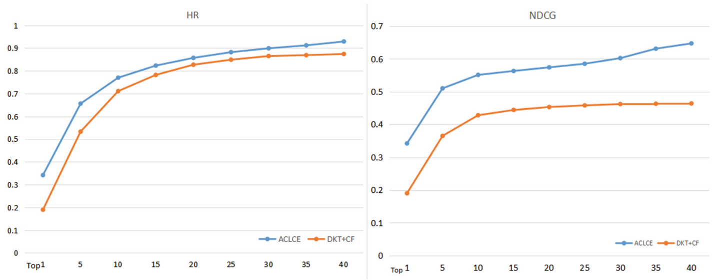

Fig. 5. ACLCE compare with DKT+CF HR and NDCG indicators at different k values.

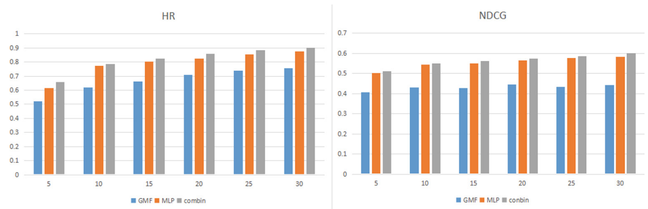

Fig. 6. NCF performance under different modules with HR and NDCG.

paper performs better in both comparisons with traditional commodity recommendation algorithms. This is because the ACLCE method considers both the individual students knowledge mastery level (DKT model) and the group nature of learning by incorporating information from similar students (collaborative filtering method) to find exercises that are similar to the students cognitive level but not mastered by the students for recommendation. The method has better accuracy and interpretability than traditional product recommendation applications and student exercise recommendation methods, and is more reliable and scalable than methods based on knowledge state modelling.

5 Conclusion

In view of the disadvantages of traditional recommendation methods that do not consider students knowledge mastery level, this paper proposes Adaptive exercise recommendation based on cognitive level and collaborative filtering. The first step of the method is to model the students knowledge mastery level by combining the deep knowledge tracking model. In the second step, the knowledge level vector of students is used as the reference to calculate similar students to get similar users, and the predicted target score vector is obtained by combining the knowledge level vector of individuals, and the group information of similar students is added while considering the individual state information of students. Finally, the validity and rationality of the proposed ACLCE method are proved by experiments.

In the following research, based on the model, We can consider replacing the cognitive diagnosis model, or adding more user behavior and exercise information to enhance the recommendation effect. Starting from the recommended scenarios, the recommendation strategy in different scenarios is also worth discussing. For example, according to the different difficulty levels, the recommended topics for expansion and improvement and the recommended topics for review and consolidation can be distinguished, so that personalized exercise recommendation can be carried out in a more targeted manner. Starting from the recommendation method, most of the advanced recommendation algorithms are based on heterogeneous graph to process the information of students and topics. In the follow-up work, we can consider establishing heterogeneous graph of interaction between students and topics, so as to use more effective information to model students and exercises to enhance the recommendation effect.

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Construction and Practice of Virtual Simulation Experiment Teaching System of Wireless Sensor Networks

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Abstract. The course of wireless sensor networks (WSN) cultivate students' engineering consciousness and ability of system development through experiments. In the past, experiments were carried out in laboratories, where validation experiments were completed with limited number of sensor nodes and local development software. Under the limitation of experiment resources, it is difficult to meet the requirements of achieving the objectives of the course. Virtual simulation technology breaks space-time constraints, and students can complete the study of experimental instructions, the compilation and downloading of codes, and the collection of experimental results online. This paper designs a virtual simulation experiment teaching system of WSN by combining virtual simulation platform with existing teaching management platform and instant communication platform. The practice shows that the introduction of virtual simulation technology improves students' learning interest, enriches experimental content and improves teaching quality, which is confirmed by q questionnaire survey.

Keywords: virtual simulation · wireless sensor networks (WNS) · communication platform · management platform

1 Introduction

Integrating information science and intelligent technology into experiment teaching, virtual simulation experiments overcome the time and space limitation of traditional experiments, which transforms the teaching mode from "Internet+education" to "intelligent+education". From 2011, two years before that the construction of national virtual simulation experiment teaching centers promoted by the China Ministry of Education, to present, virtual simulation experiment teaching has gone through three stages: exploration and trial, development and construction, and application and innovation. In 2017, the Ministry of Education laughed a four-year project of constructing national demonstration teaching of virtual simulation experiment [4]. By the end of 2020, a total of 2079 virtual simulation experiment courses have been online on the iLAB virtual simulation

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experimental teaching sharing platform, among which 728 have been recognized by the national level [3].

Based on the student-centered concept, a large number of investigations have been carried out to evaluating the teaching effects of virtual simulation experiments. Moazami et al. [5] applied traditional teaching and virtual simulation experimental teaching to 35 dentists respectively, and concluded that the latter was more effective than the former. Chao et al. [6] used virtual simulation experiment to lead high school students to understand gas laws, and found that students using this teaching method had better understanding of some concepts than the students doing traditional experiments. Based on the data obtained from 35 relevant experiments and quasi-experimental studies published in domestic and foreign journals from 2010 to 2020, Tian [7] et al. confirmed that virtual simulation teaching can improve the overall learning effect. Shao et al. [8] investigated the effect and acceptance of online virtual simulation experiments, and found that the students have a high evaluation of the completion of the experiment. The experimental space operation working group of higher education press [9] carried out the questionnaire survey of virtual simulation experiments in 2020 and pointed out that virtual simulation experiments improved the learning effect, but there are significant variations in different subjects and different learning time. Although most of the research supports the role of virtual simulation experiment teaching, some research points out the deficiency of virtual simulation experiment. For example, Darrah et al. [10] evaluated a set of virtual experiments for entry-level physics courses in universities, and found that there was no significant difference in students' scores between virtual simulation experiments and traditional hands-on physics experiments. Perez-romero et al. [11] divided students into virtual simulation group and traditional model group for 3d terrain operation and learning. Through comparative analysis of final scores, it was found that the latter score was significantly higher than the former. Sharma et al. [12] conducted Millikan oil drop experiment in the virtual simulation laboratory and found through investigation that students did not think that virtual simulation experiment could replace traditional experiment.

As a core course in Internet of things (IoT) engineering, the experiments in wireless sensor networks (WSN) integrate the experiment contents related to sensors, computers, communicators and other disciplines, which are hard to manage and required a large amount of investments to purchase and maintain experimental equipment. To overcome this difficulty, various open source simulation design software (such as Protesus, Qemu, OP NET, NS-2, etc.) [13–15] or application scene visualization platform [16] have become the choice of many colleges and universities to carry out virtual simulation experiments. Following the principle of combing the virtual and the real, the virtual simulation technology can be used to construct more realistic virtual experiments to improve the teaching quality [17].

In this paper, a virtual simulation experiment teaching system of WSN is constructed by combining virtual simulation platform with existing teaching management and instant communication platforms. A teaching process which integrates the three platforms is proposed, based on which virtual experiments have been implemented during the COVID-19 pandemic. A questionnaire survey is conducted, which shows that the introduction of virtual simulation technology improves students' learning interest, enriches experimental content and improves teaching quality.

The following of this paper is organized as below. Section 2 introduces the construction of virtual simulation experiment teaching system. Section 3 details how to apply the teaching system into teaching processes. Questionnaire survey and its analysis are provided in Sect. 4. Section 5 concludes this paper.

2 Virtual Simulation Experiment Teaching System

As seen in Fig. 1, the virtual simulation teaching system is composed of three platforms, i.e., experiment platform, management platform and communication platform. These three platforms provide the functions of student management, online and offline experiments resources, course materials, and experimental report submissons, etc., which can be used to complete the entire teaching process.

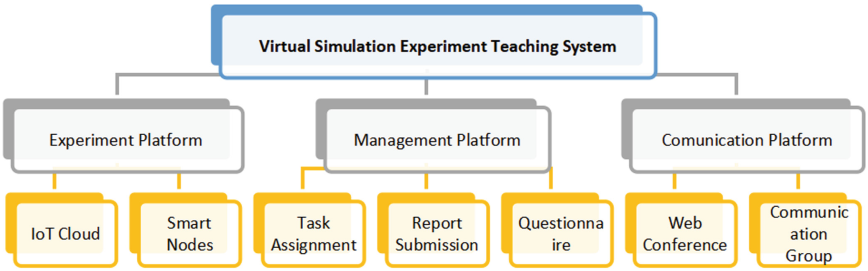

Fig. 1. Architecture of Virtual Simulation Teaching System.

2.1 Experiment Platform

OmniEdu Smart Node IoT teaching system, developed by an entrepreneurial team from Tsinghua University, is an online/offline experiment platform focusing on WSN experiments. The software part contains an online experiment management system, called IoT cloud, where users can log in the system website to conduct remote experimental operation through computers or even mobile client (mobile phone, tablet). The hardware part is composed of OmniEdu smart nodes, which are linked to IoT cloud by WiFi, and can download the code and collected the data from the interface connected with sensor nodes.

1) *IoT Cloud*

IoT cloud is an online experiment management system applied to the course related to WSN and other IoT courses. It includes the following functions:

- Management for resource, user role, intelligent terminal (*i.e., smart node*), experiment process, student class, check-in and so on.
- Monitoring for project, data source, user login history and so on.

- Report for registration time distribution, user role distribution and so on.
- Operation for experiments.

Following the instructions on the web page, one can perform experiment operations online and remotely control the Smart Nodes to download the codes onto sensor nodes and collect data from the nodes. For example, to accomplish the blink experiment, one can browse to the experiment instruction page, and following the instructions after clicking “start experiment” button, seen in Fig. 2.

Fig. 2. IoT Cloud: An Online Experiment Management System

2) *Smart Node*

Smart node is an embedded equipment with interfaces to sensor nodes and powered by 220V power supply or a built-in lithium battery. It connects to the IoT cloud through a WiFi router, and then gets instructions and uploads data by wireless link. Smart node can download codes to sensor nodes and collect data from sensor nodes. Through the sensors and actuators equipped on the sensor nodes, various experiments can be performed online or offline through smart nodes. A smart node and parts of accessories are demonstrated in Fig. 3.

Fig. 3. Smart Node: An Embedded Node with Interfaces for Sensor Nodes.

2.2 Management Platform

Although IoT cloud in the experiment platform provides management functions for the experiment, an online course management platform consistent with other courses is required in order to meet the requirements of the teaching management department. For example, in the university of Anhui Polytechnic University, an online course management platform named learning pass serves as a recommended platform widely used in online course management.

Learning pass is a platform for course learning, knowledge dissemination and teaching management based on micro-service architecture. It makes use of the massive resources of books, periodicals, newspapers, videos and original works accumulated by ChaoXing over the past 20 years, integrating knowledge management, course learning, project creation and office application, providing students with a one-stop learning and teaches with a unified working environment.

For the experiment course of WSN, a home page learning pass is built online, which can be used to provide notification, check-in, class discussion, experimental report submission and correction, questionnaire and other functions, seen in Fig. 4. After several years of use, both teachers and students have become familiar with the operations in learning pass.

2.3 Communication Platform

Online teaching platform and instant communication tool are essential for carrying out real-time online teaching activities. Since the COVID-19 pandemic, various online teaching platforms such as Tencent meeting, ZOOM, Webex, Samepage and instant messaging tools such as WeChat, QQ, DingTalk have been introduced to universities and become the main way for carrying out online education. In the practice of virtual simulation experiment teaching of WSN, Tencent meeting and QQ group are respectively used to carry out online teaching and maintain contact between teachers and students.

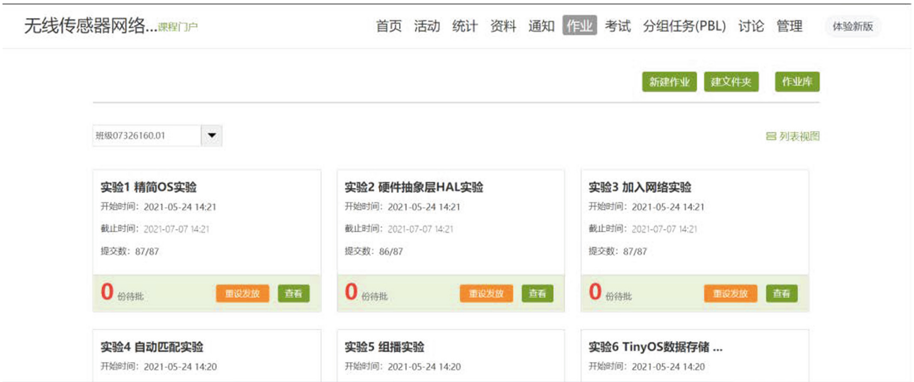

Fig. 4. Online Course Management Platform

3 Teaching Process

The teaching process of virtual simulation experiments is divided to three stages, i.e., before class, during class and after class. Experiment preparations and report submissions are completed on management platform before and after class respectively. During class, instructions and experiments including virtual simulations and traditional experiments are implemented on communication platform and experiment platform respectively.

3.1 Process Design

According to the requirements of experiment teaching and the characteristics of the three platforms, i.e., experimental platform, management platform and communication platform, the teaching process of virtual simulation experiments of WSN can be divided into three parts: before class, during class and after class, seen in Fig. 5.

1) *Before Class*

Before class, experimental tasks are distributed through the teaching management platform to guide students to prepare for the experiment. Experiment tasks are transmitted to the teaching management platform in the form of experimental instruction materials, and students are required to make experiment plans according to the experimental instructions one week before the experiment.

Meanwhile, in order to meet the programming needs of some students with strong ability, operating system images, integrated with development environments, virtual simulation tools and routine codes are provided to implement experiments locally on student computers. By programming, students can better preparation for experiments, and get the ability to carry out further curriculum design and graduation design related to the experiments.

2) *During Class*

During class, the explanation of experimental principles and the demonstration of experiment process are presented through an online conference platform. First, tasks and questions are assigned to the students after the online explanation of the content and purpose of the experiment. Then, login of virtual simulation platform and experiment process are demonstrated by screen sharing. Finally, the teacher ends the online meeting after answering the students' questions. During the experiment process, in order to construct an interaction between the teacher and the students, an online course group should be established through chat software, so that teachers and students in the group can interact in real time during the experiments or even before and after the experiments.

The virtual simulation platform experiment is carried out online. After logging in to the online experiment platform and reading the experiment instructions and other relevant materials, the students enter an experimental page to complete the code download, compilation, running, experimental phenomenon observation and experimental data collection. Considering that the experiment routine code is only used for the verification of phenomena, coding and debugging are also required, which can be implemented offline and online on the platform. In the laboratory, it is preferred to coding online which simplifies the maintaining the development environment, but the capability of offline coding is also require because of practical use.

Considering that the ultimate goal of the experiment is to make students master the practical application and development ability of WSN, the experimental platform combined with virtual and real is more suitable for the teaching of WSN experiment course. Therefore, if conditions permit, students can still go to the lab to finish the experiments, and observe the experimental phenomena (such as LED flashing, serial communication effect and the feedback of various actuators) directly. On the one hand, students can use the experimental platform to operate physical nodes, which is convenient for the management of the laboratory. On the other hand, students can also operate physical nodes directly with a computer installed with integrated compilation environment.

3) *After Class*

After class, teaching management system is used to complete the experiment report submission and correction and curriculum questionnaire collection. Although the experimental platform has the function of submitting experimental reports, for convenience, we use the teaching management platform recommended by the Teaching Affairs Office to collect electronic experimental reports and complete the correction. Compared with paper experimental reports, electronic experimental reports can not only reflect students' experimental preparation and experimental results, but also master the experimental process through pictures, videos, program codes and other materials, so as to better evaluate the achievement of ability. The questionnaire function is also provided by the teaching management platform, which can be used to generate questionnaires distributed to students after the experiment to get feedback on the experiment content and process.

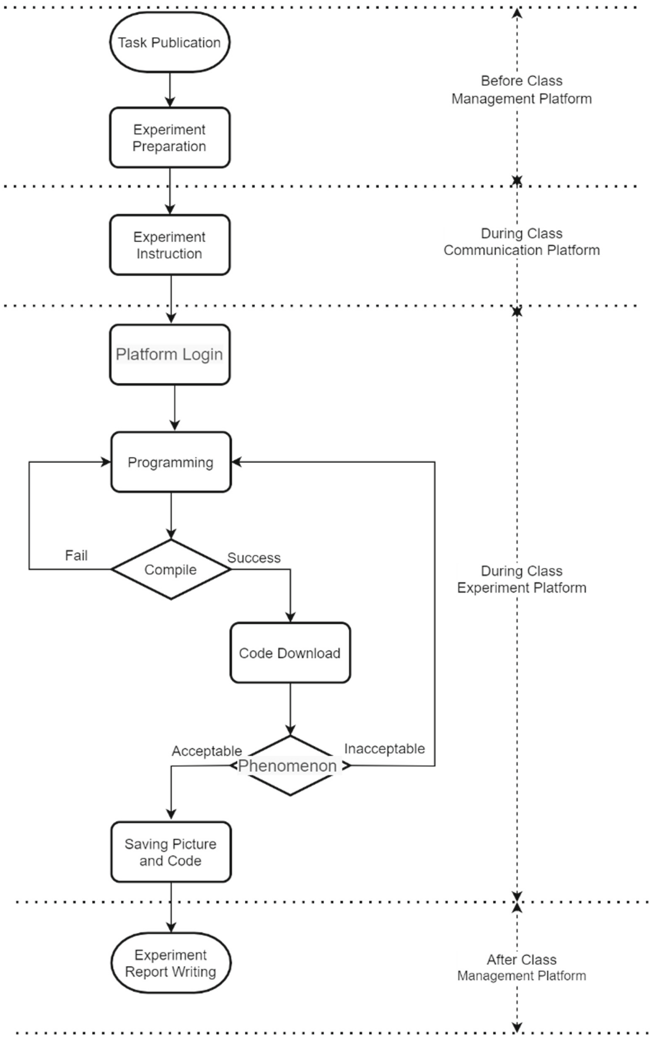

Fig. 5. Flow Chart of Teaching Process.

3.2 Implementation

The construction of WSN virtual simulation experiment teaching system began in 2020. At that time, due to the impact of COVID-19, a large number of hardware development experiments, including WSN experiments, could not be carried out online. Therefore, the WSN virtual simulation experiment teaching and research project was declared and approved, and the virtual simulation experiment construction was carried out by making full use of existing resources. After one year of construction, the experimental teaching system of WSN course combining virtual and real has been initially built. It will be tested for iot level 18 students in the first half of 2021, and will be improved according to the test results.

In the first half of 2022, the Novel Coronavirus Omicron variant swept the world, and our city fell silent for a week. During this period, all courses of the school need to be carried out online, including WSN experiments. Therefore, we use virtual simulation technology to complete an experiment. The following is a brief introduction to the actual development process.

After receiving the notice from the school, the teacher arranged the virtual simulation experiment and communicated with the students through QQ group in the first time, urged the students to read the experiment instructions and complete the preparation work of the virtual simulation experiment. On the day of the experiment, the teacher entered the laboratory in advance, opened the virtual simulation platform, checked the experimental equipment, and issued the login account and password. The login account can be divided into two types. One is the personal account associated with the student id, which is used for consulting experimental data and downloading and debugging experimental codes. The other type is the device account associated with the student dormitory, which is used by the student to burn the compiled code to the Smart node online for verification.

After the experiment class began, the teacher first arranged the experiment tasks through Tencent meeting, introduced the experiment principle and demonstrated the experiment process. Then, students carried out the experiment according to the content of the experiment guide and the teacher's explanation, and burned the code to the Smart Node node through the dormitory associated account to observe the phenomenon. Because the experimental phenomenon of this experiment not only includes the experiment log on the virtual simulation platform, but also the LED flashing on the sensor node. In order to intuitively understand the experimental phenomenon, at the request of students, teachers were instructed to shoot the experimental phenomenon video of the laboratory hardware equipment and upload it to QQ group, so as to interact with students in real time and answer their doubts. After class, students will take pictures of the handwritten experimental report and upload the screenshots of the experimental process to the homework module of the superstar Learning Platform to complete the submission of the experimental report.

In order to understand the experimental effect, a questionnaire was also issued after this course. The content and results of the questionnaire are shown in the next section (Fig. 6).

4 Questionnaire and Analysis

On April 21, 2022, an online virtual simulation experiment of WSN was carried out for 81 students majoring in Internet of Things Engineering. After the class, a questionnaire was distributed and 77 valid answers were collected. There are 9 multiple-choice questions in the questionnaire, which respectively focus on students' background of virtual simulation experiment, the comparison between traditional experiment and virtual simulation experiment, and their feelings after virtual simulation experiment. Through the feedback of the questionnaire, we hope to get the students' real views on virtual simulation experiments and explore an experimental teaching system that can give full play to the advantages of virtual simulation through the combination of virtual and real.

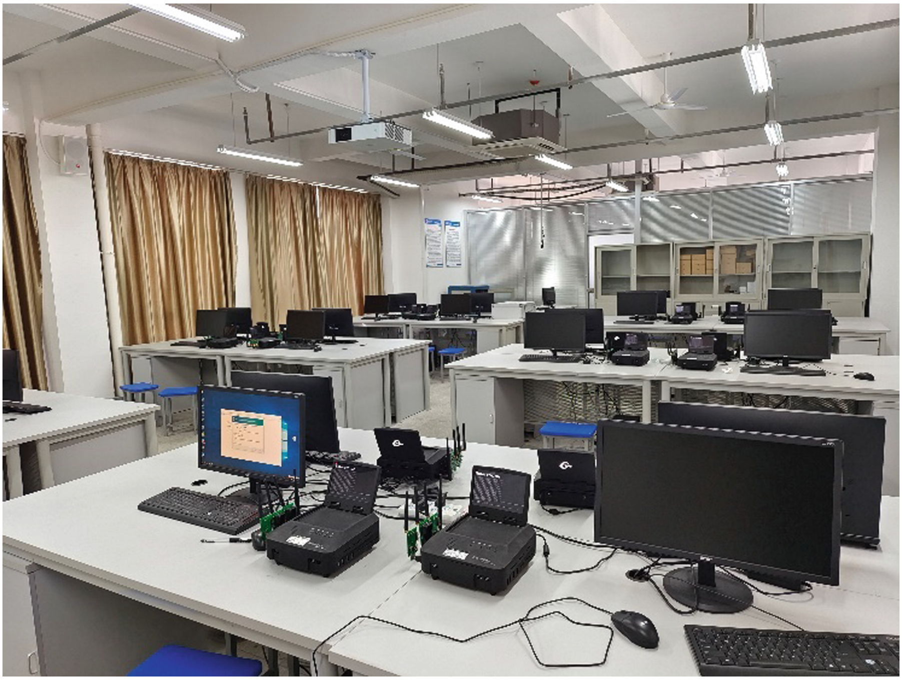

Fig. 6. Implementation Environment of Virtual Simulation.

4.1 Background of Virtual Simulation

In order to investigate students' understanding of virtual simulation, the survey of "background of virtual simulation" is conducted. In the survey, we find that 98.7% students have a certain understanding of virtual simulation, and 7.9% of them think they have a very good understanding of virtual simulation. The proportion of students who have participated in virtual simulation experiment is 88.2%, which means virtual simulation experiments have been conducted by other course before WSN. Almost all of the students expressed interest in the virtual simulation experiment and were willing to participate in the learning of imitating the real experience. This shows that the virtual simulation experiment can stimulate students' interest in learning, improve students' attention, and play a positive guiding role in promoting teaching. The survey results are shown in Table 1.

Table 1. Background of Virtual Simulations

	Options	Percentage
Knowledge of virtual simulation	Familiar	7.9%
	Known	90.8%

(*continued*)

Table 1. (*continued*)

	Options	Percentage
	Unknown	1.3%
Participated in virtual simulation experiment before	Yes	88.2%
	No	11.8%
Interested in virtual simulation experiment	Very interested	40.8%
	Interested	56.6%
	Not interested	2.6%

4.2 Comparation of Traditional Experiment and Virtual Simulation

Although traditional experimental teaching has many shortcomings, the students are not unanimous in their opinions. In our survey, 34.7% of the surveyed students thought that there were limited resources related to experimental instruments and contact time. Limited by time and space, the inability to repeat experiments is also an obvious deficiency in traditional experimental teaching (23.6%). 20.8% of the students thought that they only did experiments to obtain experimental data and complete experimental reports, and had insufficient understanding of Experiment. At last, 17.4% of the students expressed low interest (29.62%) and other factors accounted for less (3.5%).

Similar to the survey results for the shortcomings of traditional experimental teaching, the students are not unanimous in their opinions on the advantages of virtual simulation. More than 30% of the surveyed students believe that the breakthrough of time and space constraints and independent inquiry learning are the advantages of virtual simulation experiment. 28.9%, 19.7 and 18.4% of the students chose autonomous inquiry, interactive operation and immersive learning respectively. Less than 3% of students thought virtual simulation Broaden the breadth and the depth of the experiments. In a word, the advantages of virtual simulation are not significant compared with traditional experiment.

However, according to the survey, 92.1% of the students hope that the teachers can combine the simulation experiment with the traditional experiment. The traditional experiment focuses on cultivating students' practice ability, and the virtual simulation simplifies the hands-on process but Emphasizes programming skills. During the COVID-19 pandemic, online virtual simulations greatly promoted the development of the experiment teaching, make the student conduct experiments in dormitory, which reduces the negative impact of the epidemic.

The survey results are shown in Table 2.

Table 2. Comparation of Traditional Experiment and Virtual Simulations

	Options	Percentage
Shortcomings of traditional experiment	Limited in resources	34.7%
	Cannot repeat	23.6%
	Just to get experimental data and complete experimental reports	20.8%
	Low interest	17.4%
	Others	3.5%
Advantages of virtual simulation	Immersive Learning	18.4%
	Autonomous inquiry	28.9%
	Interactive operation	19.7%
	Broaden breadth and depth	2.6%
	Break through the limitations of time and space	30.4%
Combination of the virtual simulation and traditional experiment	Hope	92.1%
	Don't care	6.6%
	Hope not	1.3%

4.3 Evaluation of Virtual Simulation

Combined with the conducted "TinyOS data storage experiment", the survey was carried out to investigate the cognitive comparison of students on the difficulty of the experiment. According to the surveys, 10.5% of students think the experiment difficult is hard, 82.9% think it is normal, and 6.6% think it is easy. In the teacher's opinion, the difficulty of this experiment is relatively high. But since the experiment instruction and the basic code are provide by the experiment platform, students focused on the code related to data storage, which effectively reduced the difficulty of the experiment.

From the survey, 42.1% of the students have a high degree of self-satisfaction and think that the completion of the experiment is good, and 56.6% of the students think that their completion degree is average. In addition to the technical problems, most of the students expressed that the main factors affecting the completion of the experiment were unfamiliar operation steps, unknown details, insufficient understanding of theoretical knowledge and other problems, and these problems are often encountered in the routine laboratory operation. In addition, based on the online virtual simulation experiments, each school has done corresponding training for virtual simulation experiments, and optimized the experimental instructions.

The virtual simulation of the real experiment has a unique advantage in teaching and learning reflection before and after class. "TinyOS data storage experiment" online program can be according to the students with the link of the operation and comprehensive design performance evaluation, help the student to analyze the basic code, revise the code to achieve various data storage function, and obtain satisfactory experiment report. In the virtual simulation system, students can constantly "re-test" to strengthen the practical operation skills, which can achieve the same purpose as the actual laboratory operation. From the survey, more than 98% of students solve problems in experimental operation through teacher-student communication and self-search, which has a positive meaning for cultivating students' thinking ability and innovation consciousness.

The survey results are shown in Table 3.

Table 3. Evaluation of Virtual Simulations

	Options	Percentage
Experiment difficulty	Hard	10.5%
	Medium	82.9%
	Easy	6.6%
Experiment performance	Good	42.1%
	Average	56.6%
	Bad	1.3
How to solve the problems encountered in virtual simulation	Self-search information	36.9%
	Communicate with classmates and teacher	61.3%
	No problem	1.8%

5 Conclusion

The construction of virtual simulation teaching system is essential to fulfill the requirements of online teaching and improve the experiment quality. Based on the practice in the virtual simulation experiments of WSN, integrating virtual simulation technology into the existing teaching process can stimulate students' interest in learning and reduced the difficulty of the experiment. Facing with the limitations of virtual simulation, it is suggested to combine the simulation experiment with the traditional experiment to cultivate students' practice ability as well as programming skills, which reflects the characteristics of the talent cultivation in IoT engineering subject.

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Learning Situation Risk Cognition and Measurement Based on Data-Driven

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Abstract. At present, online teaching has become more and more popular especially in the context of the current epidemic, and quality governance has become the internal needs of modern education development, while there is no simple and easy to use learning situation risk cognition method for specific online teaching class. In order to deal with this problem, in this study a data-driven method of learning situation risk cognition and measurement for online teaching is provided, which uses student initiative degree, concentration degree, duration degree and interaction degree to measure comprehensive learning effective degree and reflect student learning situation risk in an online class. Besides, normalized score earned by student in knowledge point test after online class is used to validate the calculation method designed, and the obtained results show that it is promising and easy to calculation. It provides a basis for decision making of students' learning situation risk early warning and also provides a data-driven management method for the guarantee of online teaching quality, which has both academic and practical significance.

Keywords: Data Driven · Learning Situation Analysis · Risk Cognition

1 Introduction

At present, quality governance and the construction of high-quality education system have become the internal needs of educational reform and development. Learning situation refers to the situation about students learning in class. Learning situation risk cognition is to discover factors affecting learning and measure failing risk of student's learning. The research on learning situation risk cognition can provide decision-making basis for targeted teaching measures and efficient learning direction determination, so as to reach better design of teaching, personalized learning accuracy, and quality improvement of the whole education.

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2 Related Research Analysis

2.1 Measurement Index

The selection of learning situation risk analysis index is directly related to the adequacy and comprehensiveness of learning situation risk cognition. At present, there are two main categories of index. The first category is related to course learning, including in-class indicators such as attendance, answering questions and other performance in class [1] and extracurricular indicators such as reading behavior and participation in extracurricular activities [2]. These indicators are effective scales for students' learning process and results, and can directly reflect students' learning performance and defects. The second is the index related to students' background information, including demographic indicators such as gender and age [3] and social relationship indicators such as learning group and community participation, family support [4]. Different performance of such indicators will lead to different learning behaviors, attitudes and styles, which can indirectly reflect students' academic achievement ability and potential risks. However, most of these current studies involve too many indicators. For example, 70 indicators are used in the online learning environment evaluation model [5]. So it not only hard to calculate but the obtained results also lack of timeliness. Besides, the indicators used in these studies are often too macro to be directly applied to a specific online class learning situation risk cognition.

2.2 Calculation Method

Learning situation risk calculation is mainly based on data mining technology which can be traced back to the early 21st century, and there are mainly two categories of relevant researches. The first one is to directly apply statistical methods to study the influencing factors of learning performance and to do simulation analysis for predicting learning result. For example, the retention rate and final score of students in online courses are analyzed by discriminant analysis [6]; the students with poor learning performance are detected by factor analysis [7]; the early indicators of learning success or failure are identified by logistic regression and used to predict learning risk [8]; the students' learning performance is predicted by principal component analysis and multiple linear regression analysis [9]. The second one is to use machine learning methods to predict students' learning performance. For example, the decision tree and association rules are used to identify potential students with poor academic performance [10]; the support vector machine is used to early detect undergraduates with difficulties in course learning and to predict their academic performance in the next semester [11]; the Bayesian algorithm is used to predict the academic performance of students [12]; the weighted mode is combined with the naive Bayesian method for academic early warning classification [13]; the artificial neural network [14], genetic algorithm [15] and fuzzy comprehensive evaluation [16] methods are applied to predict students' course academic performance and early warning of learning failure risk. It can be seen that the theoretical research on learning risk cognition methods has shown the characteristics of algorithmization and automation. These new attempts are promoting the deep integration of data-driven technology and learning situation risk cognition, but most of them still stay in the research stage of model construction, and there are still few studies that can really transition from algorithm model to practice application in a specific online class.

2.3 Application Practice

In the practice of learning situation risk research, it has shown the emerging development trend of digitization, systematization and specialization. For example, based on data analysis of students' course learning process, the course signal and Purdue signal projects in Purdue University can provide students with their performance information in time; moreover, through the SSA (student success algorithm) algorithm, students in academic crisis can be judged and warned, which is very helpful to promote students to improve their success rate of curriculum learning [17, 18]. The Pennsylvania State University builds a data-driven student academic performance prediction model based on 8.5 million student data, which can identify students who may be at risk through comprehensive evaluation and help the school management department formulate intervention strategies in advance [19]. The University of Alabama, Arizona University and University of Maryland also conduct relevant research and practical exploration on predicting at-risk students using multi-source data, which is very helpful to improve students' academic success and retention rate [11]. In addition, the student success system developed by Desire2Learn, the learning dashboard developed by Khan college, the starfish early warning module of starfish enterprise success platform, the prediction and early warning application system developed by University of electronic science and technology [20] and the postgraduate education management information platform for quality monitoring and early warning developed by Nantong University [21] also have learning situation early warning related functions based on learning data analysis, which are helpful to reduce students' learning risk and improve academic quality.

However, most of these present practices often focus on the disclosure of student's learning problems throughout the whole semester rather than giving risk information immediately after a class, while the latter has better value for promoting students to adjust their learning strategies in time and improve the quality of their current studies. In the context of the current epidemic, online teaching has become more and more popular, so there is an urgent need to develop a simple and easy to use learning situation risk cognition method for specific online teaching class.

3 Data and Method

3.1 Data Collection and Preprocessing

In this study the data from the Tencent meeting software used as online teaching tool is used for learning situation risk cognition and measurement modeling. The knowledge point testing data after class from the Chaoxing teaching platform is used from model validation. The details are shown in Table 1.

The preprocessing needed include: 1) at the end of a class, if students do not actively quit Tencent conference software, the finish time of their class will be lost. At this case, it will be filled with the default end time of this class; 2) the interaction of students in class

Table1. The Details of Basic Source Data

Phase	Source	Content
study in online class	Tencent meeting software	cumulative meeting (class) duration, total number of participants, scheduled start time, scheduled end time, user nickname (joining nickname), first joining time, last leaving time, joining times, cumulative participation duration, identity, etc
knowledge point test after class	Chaoxing teaching platform	visiting time, submission time, total score, score of each question type, etc

recorded by the Tencent meeting software is a specific record of their interaction with teachers every time. It needs to be manually counted to get the number of interactions of each student; 3) the score earned by student in knowledge point test after class should be normalized in order to remove the different unit effect; 4) data from different sources need to standardize the student's ID number so that all data can be integrated for following learning situation risk cognition calculation.

3.2 Calculation Method Implementation

This study focuses on the measurement of learning situation risk in online class mainly from the perspective of students' investment in online teaching. Based on the formation mechanism of learning situation risk, considering the universality and calculability of indicators, and the timeliness of the application of risk results, it is mainly calculated from four aspects.

First, initiative degree (denoted by a) is used to describe the enthusiasm of students to participate in class, which is determined by (1). Where tClassEnd is the scheduled end time of current class; tStuFirstEnter is the first time of a student entering the class; tClassBegin is the scheduled start time of current class.

$$\mathrm{a} = \mathrm{MIN}\left(\frac{t_{ClassEnd} - t_{StuFirstEnter}}{t_{ClassEnd} - t_{ClassBegin}}, 1\right) \tag{1}$$

Second, concentration degree (denoted by b) reflects whether students have external factors that lead to distraction during class. In the specific calculation, it is expressed by the reciprocal of offline times shown in (2), where noffline means the total offline times of a student during current class.

$$\mathrm{b} = \frac{1}{n_{offline}} \tag{2}$$

Third, duration degree (denoted by c) indicates whether students have been taking classes seriously during the whole class time. It is calculated by (3), where spanStuCumAtt is the cumulative time of a student attending current class and spanClassDur is the scheduled cumulative duration of current class.

$$\mathrm{c} = \mathrm{MIN}(\frac{span_{StuCumAtt}}{span_{ClassDur}}, 1) \tag{3}$$

Fourth, interaction degree (denoted by d) measures whether students are interested in this class and how deep they participate in teaching. It is quantified by (4), where ninteraction is the number of a student's interaction times during current class.

$$\mathrm{d} = \begin{cases} 1.0 \text{ if } \mathrm{n_{interaction}} \geq 3 \\ 0.9 \text{ if } \mathrm{n_{interaction}} = 2 \\ 0.8 \text{ if } \mathrm{n_{interaction}} = 1 \\ 0.7 \text{ if } \mathrm{n_{interaction}} = 0 \end{cases} \tag{4}$$

At last, the values of initiative degree, concentration degree, duration degree and interaction degree are integrated together as comprehensive learning effective degree (denoted by x) using multiply operation shown in (5), and the final learning situation risk level (denoted by y) is determined by (6), where 0 represents no risk, 1 indicates low risk, 2 means medium risk and 3 denotes high risk, which can be easily understood and used by teachers and students in learning situation risk early warning education.

$$\mathrm{x} = \mathrm{a} * \mathrm{b} * \mathrm{c} * \mathrm{d} \tag{5}$$

$$\mathrm{y} = \begin{cases} 0 \text{ if } 0.75 < x \\ 1 \text{ if } 0.50 < x \leq 0.75 \\ 2 \text{ if } 0.25 < x \leq 0.50 \\ 3 \text{ if } x \leq 0.25 \end{cases} \tag{6}$$

4 Result and Analysis

Taking one online class in software project management course this year as an example, the calculated results of learning situation risk cognition is shown in Fig. 1. For a total of 51 students, there are 9 students with high risk, 7 students with low risk, 23 students with medium risk and 12 students with no risk. From this point of view, we can know that most students perform well in online teaching classes, while a small number of students need to be given early warning in time to help them improve their learning quality.

For further validating the effectiveness of our method designed in this study, the normalized score (denoted by s) all students earned in knowledge point test after the online class was used to do correlation analysis. The calculated correlation coefficients between normalized score and initiative degree, concentration degree, duration degree, interaction degree, comprehensive learning effective degree is 0.78, 0.07, 0.54, 0.29 and 0.42 respectively as shown in Table 2. From which we can know that all calculation indexes used in this study can reflect student learning effects and quality. Among

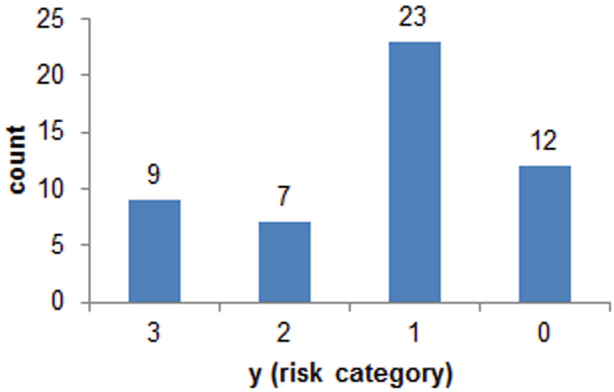

Fig. 1. Distribution of calculated learning situation risk

them the initiative degree has the biggest correlation with student score; the comprehensive learning effective degree has relatively good correlation with student earned score. However, we can not only measure students' learning situation by their participation initiative enthusiasm, because this will lead to the incompleteness of learning situation risk cognition (Table 3).

Table2. THE RESULTS OF CORRELATION ANALYSIS

	a (initiative degree)	b (concentration degree)	c (duration degree)	d (interaction degree)	x (comprehensive learning effective degree)
s (normalized score)	0.78	0.07	0.54	0.29	0.42

Table3. THE RESULTS OF ANALYSIS OF VARIANCE

	df	SS	MS	F	Significance F
regression analysis	1	0.689379	0.689379	10.279860	0.002369
residual error	49	3.285993	0.067061		
total	50	3.975372			

Besides, from the results of analysis of variance between x and s, we can see that the value of Significance F (0.002369) is less than the significance level $\alpha = 0.05$, which indicates that there is a linear correlation between x and s. So in summary, the method used in this showed effectiveness and could be used to measure student learning situation risk cognition in online course study.

5 Conclusion and Prospect

In this study, a data-driven method of learning situation risk cognition and measurement for online teaching is provided. The validation results show that it is convincible and easy to calculation. It provides a basis for students' learning situation risk early warning without teacher supervision during the epidemic, and also provides a data-driven management method for the guarantee of online teaching quality, which has good practical application value.

However, the ultimate goal of learning risk cognition is to improve teacher's teaching and promote student's learning [22]. The research on learning risk cognition cannot just stay on identifying students' learning risk, but also need to put forward targeted intervention measures and prescription improvement schemes to lead to essential improvement of learning quality. Therefore, the next step will be to explore personalized intervention and improvement strategies based on multimodal data fusion [23] and learning situation big data analysis.

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A C Language Learning Platform Based on Parsons Problems

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Abstract. The C programming language(C) is not only an essential basic core course for computer-related majors in domestic higher education, but also a compulsory basic course for many other non-computer majors. Due to the high cognitive load caused by the writing code method of traditional practice methods in learning programming languages, some novices without programming experience have difficulty in understanding and applying this language. Based on the main difficulties brought by the writing code practice method in the process of learning C for novices, this paper designs and implements a C learning platform based on Parsons problems. The platform makes it easier and more effective for beginners to learn the C by practicing in a low cognitive load by using Parsons problems, this method only requires students to complete the exercises by dragging and dropping code blocks, and the system can adaptively adjust the difficulty of the exercises according to the feedback of the students' behavior during the exercise, so that the difficulty of the exercises is more suitable for the students' current knowledge level. The platform provides a good support environment for the C learning novices to study in class and practice after class.

Keywords: C programming language learning · Parsons problems · Learning platform

1 Introduction

In this information age, programming is a very useful skill, and many universities choose C as the first programming language for students. But programming language beginners usually think that learning C is difficult, mainly because beginners often make some simple mistakes in the process of writing code and then lost confidence, such as syntax errors or input and output errors, etc. The main factor of these simple mistakes is novices are not clear about grammar rules and code specifications [1, 2]. Most current C courses require students to manually write code from scratch to complete the exercises, but write code is a high cognitive load task for beginners who do not have a solid grasp of the basics [3], which can cost them a lot of time to solve simple mistakes in the code written process, but the rewards are very low, and even get into learning dilemma [4]. Due to the poor grasp of the strict syntax rules and code specifications of the C, beginners always have difficulties due to grammatical errors in the code writing practice from zero, which seriously dampens the enthusiasm of beginners to learn.

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In order to solve the writing code difficulties faced by beginners in learning C, a method with relatively lower cognitive load and a learning effect equivalent to traditional writing code exercises is needed. Parsons problems is one such approach. Parsons problems are a type of code completion type of exercises that students do not need to code manually. The exercises provide alternative code that contain all the code to solve the problem and extra code of distraction, which are divided into different code blocks by line and then randomly shuffled. Students only need to drag and drop the correct code blocks from the out-of-order blocks to the right to restore its correct order which can solve the problem [5]. Compared with the two traditional programming learning methods of write code and fix code, in the learning of the same problem, students spend significantly less time on Parsons problems type exercises, but the learning effect is equivalent [6, 7]. In addition to having the advantage of low cognitive load, students also showed higher interest in practice in the form of Parsons problems compared to practice in the traditional way of writing code and tracking code [8]. Therefore, Parsons problems has a greater advantage than the traditional write code practice method. But at present, the research and application of Parsons problems mainly focus on languages such as Python, there is not much research about it in C, and there is very little application in the actual teaching environment.

This paper designs and implements a C learning platform based on Parsons problems. The main design goals of this platform are:

(1) Provide Parsons problems exercises to effectively reduce novices' learning cognitive load.
(2) Provide a friendly operating environment for novices, just simply drag and drop to complete the exercises.
(3) Can adaptively adjust the difficulty of the exercises according to the feedback of the students, which can effectively improve the learning efficiency.

2 Related Work

In the current programming language teaching environment, students often learn in the traditional way of writing code, which may cause beginners to spend hours just to find a simple syntax error in the program [9]. Some studies believe that the reason for this inefficient learning behavior is that this is related to the fact that write code is a high cognitive load learning method for beginners in programming, and effective learning usually requires a reduction in cognitive load [10]. The high cognitive load learning method will consume a lot of time for students, but the learning effect is average, and it will even damage students' learning confidence [3]. One potential way of learning is to provide students with a way that has a low cognitive load while still learning effectively. In this way, students can learn easily and maintain the effectiveness of their learning.

The Parsons problem is a learning method that includes two characteristics: low cognitive load and effectiveness, and because of these two characteristics, it has received widespread attention from educational technology researchers in recent years. Parsons problems is a drag-and-drop, out-of-order code blocks-based program construction practice method. It was originally proposed based on the Turbo Pascal language to assist students in learning the basic sentence patterns and grammar of Turbo Pascal by Parson [5]. Parsons problems provides students with all the code they need to solve the problem and distractors with wrong order, simply done by restoring the correct order of code blocks. Because this practice method is a complete practice, rather than the writing code from zero, it is relatively low in its own cognitive load. The study found that Parsons problems is a low cognitive load learning method for students [11]. The Parsons problems include a variety of forms, and many variants have occurred during its development, such as adding interference blocks, difficulty adaptability, fade Parsons problems, and so on. The Parsons problems can be applied to different learning areas in different forms, but its most basic low cognitive load and learning effectiveness are unchanged. Parsons problems without any distractors (ie, no redundant blocks) is the initial and the simplest version. If distractors are added, research based on the Looking Glass block programming environment shows that will significantly increase the difficulty of the exercise [12]. But students can learn better about grammatical and logical errors by adding distractors, such as adding distractors with grammatical or semantic errors, which are designed to highlight common mistakes made by newbies [13]. Although the addition of distractors will increase the difficulty of the problem, especially for some students with poor foundation, experiments show that students think that the distractor of Parsons problems is helpful [5]. The difficulty of the initial Parsons problems is irregular. Once the design is completed, the difficulty will be fixed and cannot be changed. You can only redesign the topic to change the difficulty. The degree of knowledge of knowledge is different, so the difficulty of the topic may cause serious trouble to some students with poor basic knowledge. The emergence of adaptive Parsons issues is because of the way to make this method more suitable for students with different degrees of knowledge. In order to make the question difficulty more suitable for students and more adaptable, Ericson evaluated the adaptive Parsons problems that can automatically adjust the difficulty of the question, and the experiment proved the effectiveness of the adaptive Parsons problems [14]. Studies have shown that exercises which can dynamically adapt difficulty (based on student performance and feedback) can effectively improve student efficiency and engagement [15]. Haynes and Ericson designed exercises in the form of Parsons problems with adaptive difficulty, and compared them with traditional write code methods to compare the effectiveness and cognitive load of the two methods. The experimental results show that the learning effect of adaptive Parsons problems is equivalent to that of writing code, but the cognitive load is lower, and it is more popular with students [16]. These studies show that the low cognitive load and learning effectiveness of the adaptive Parsons problems, while at the same time, have high efficiency, and because of its difficulty adaptive characteristics, it is more suitable for the actual learning process of students.

Although there are many studies on Parsons problems, they are basically based on theoretical studies, and very few are actually applied in the classroom teaching environment. Moreover, most of these studies are based on Python [6, 8, 13, 14, 16], and some are based on languages such as Pascal [5] and Java [17], here are few applications and researches in C, and even less in practice teaching. For example, although their is one research which based on the C, but they only use Parsons problems as one of several question types in the final exam, rather than a learning means [18].

To sum up, there are many studies on Parsons problems, but very few studies and applications based on the C. Combined with the current teaching characteristics and needs of C courses, and C learning novices also need to learn in a low cognitive load way during the learning process, which can not only learn more efficiently, but also build confidence in learning programming. Therefore, this paper applies Parsons problems to the teaching and learning process of the C, designs and implements a C learning platform based on Parsons problems, which enables novices to learn effectively with a low cognitive load method, and can effectively help beginners to learn C programming syntax and code specifications, build learning confidence, and build a good foundation for their future programming work. At the same time, we can also use this platform to study the specific utility of the Parsons problems in the actual teaching environment. For example, the effectiveness and efficiency of the Parsons problems in C teaching, and establish a data basis for the application research in the Parsons problems in the actual C teaching environment.

3 Design and Implementation

3.1 System Architecture

The system architecture design of the C learning platform based on Parsons problems is shown in Fig. 1. The platform adopts B/S architecture, it is mainly divided into two parts: front -end and back -end. The front -end mainly includes the choice and practice interface of the exercise, and the back -end mainly includes the interaction with the front end and the database. The interaction with the front end includes providing exercise data and user information The interaction of the database includes obtaining and storing student data, exercise data, and submitting data from the database. And the platform includes persistence layer, business layer and presentation layer. Different levels are responsible for different things and realize the corresponding functions. The Parson problem of the platform is based on C. Students can learn C by doing exercises in the form of Parsons problems through this platform.

Persistence layer: Interact with MySQL for CRUD transactions, complete the mapping between entity classes and SQL through the DAO interface, and use it to read exercise information from the database and store students and their learning information.

Business layer: Control the relationship between different objects through Spring IOC, complete various Spring transaction processing, and manage Mybatis sessions. It is mainly used to achieve self-adaptation of difficulty. After obtaining interactive feedback from students through the presentation layer, the difficulty of exercise is adjusted accordingly.

Presentation layer: After receiving the request form the front-end page, find the controller according to the XML annotation, control the operation authority and page loading through AOP aspect programming, and finally get the model data to fill the view. Which is mainly used to provide the exercises of Parsons problems, create the front-end browser page for student practice.

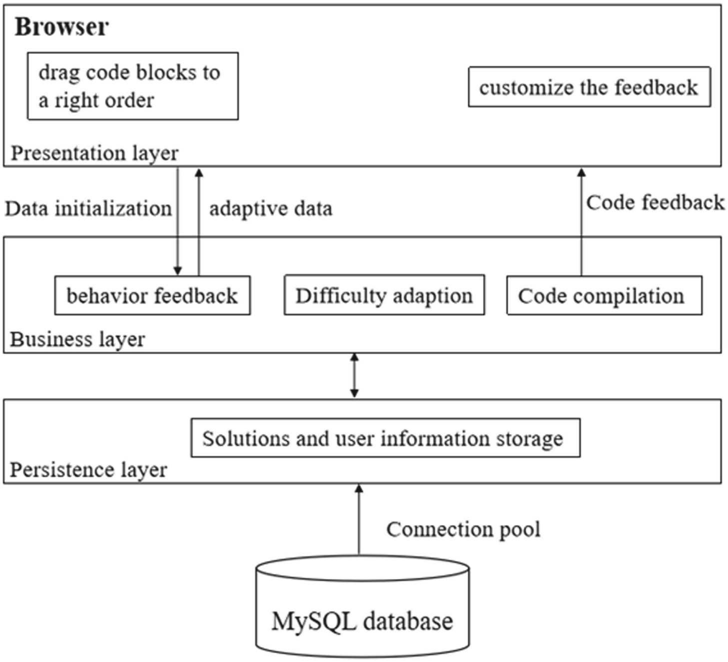


Fig. 1. The architecture of C language learning platform based on Parsons problems.

3.2 Interface Design and Platform Interaction

The student practice interface design of the platform is shown in Fig. 2. The left side of the exercise interface are all the code blocks needed to solve the problem, including distractors, and the order is random. The right side is the students' code area, this area is used to place code blocks dragged by students from the out-of-order code area on the left to solve problem. There are three buttons at the bottom of the page: the first "Resume out of order" means to return to the initial state of the question, and the order of recovery is different each time, but they are all out of order; the second "Help" button, when the student find they are in difficulty when completing this question, he can click for help, and the program will give corresponding prompts; the third "Submit" button is when students complete the sorting operation of code blocks, the system will give feedback after clicking, prompting errors or passed. Students can click different buttons according to different needs to learn more efficiently.

The interaction process of the platform is shown in Fig. 3. The platform interaction is simple and easy to use. Students can complete the exercise through simple drag-and-drop interaction operations. After completion, click "Submit" to verify whether the answer is correct. After the student submits the answer, the system obtains the code blocks submitted by the student, converts them into code, and puts the code into the compiler to compile. If the compilation fails, it means that there is a syntax error in the code, and the system will give feedback to the student that there is a syntax error, and locate the code block submitted by the student according to the error message given

Fig. 2. Learning platform practice interface.

by the compiler, then mark the first error code block as a prompt. If the compilation is successful, then input the test sample to test whether the output result is correct. If the result is incorrect, it means that there is a logic error in the code submitted by the student. The system will give feedback to the student that there is a logic error, the output result is wrong, and provide the wrong output and the correct output to as students' reference; if the result is correct, the system prompts the question passed. The overall algorithm sequence diagram of the platform is shown in Fig. 4.

3.3 Implementation of Adaptive Difficulty Mechanism

Difficulty self-adaptation mainly adjusts the difficulty of the questions according to the feedback of the students, so that the difficulty of the questions is more in line with the students' abilities, which can avoid repeated failures of students with poor knowledge and loss of confidence in learning, and can also help the students with better knowledge to enhance their understanding and application of knowledge. The difficulty adjustment of the questions includes two aspects: the difficulty within the question and the difficulty between the questions (the difficulty of the next question). Because the difficulty involved in the difficulty of adjustment is different, so the difficult adjustment mechanism in both aspects is slightly different. The specific implementation mechanism is as follows:

Adaptive difficulty within the question: The adaptation of the difficulty within the question is adjusted by the active feedback of the students, which is realized based on the help button of the practice interface. When the student presses the help button during practice, it indicates that he has encountered difficulties in this question and needs help,

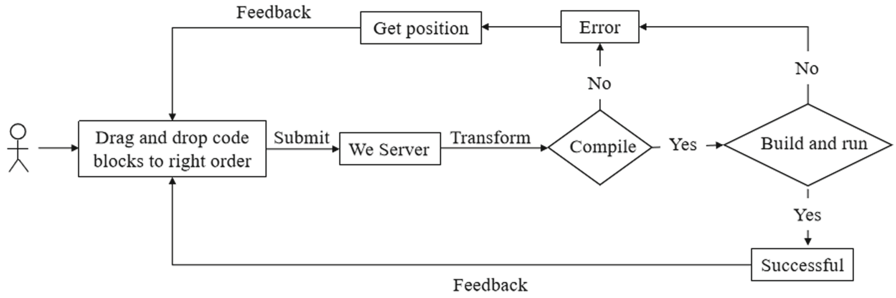


Fig. 3. Learning platform interaction flowchart.

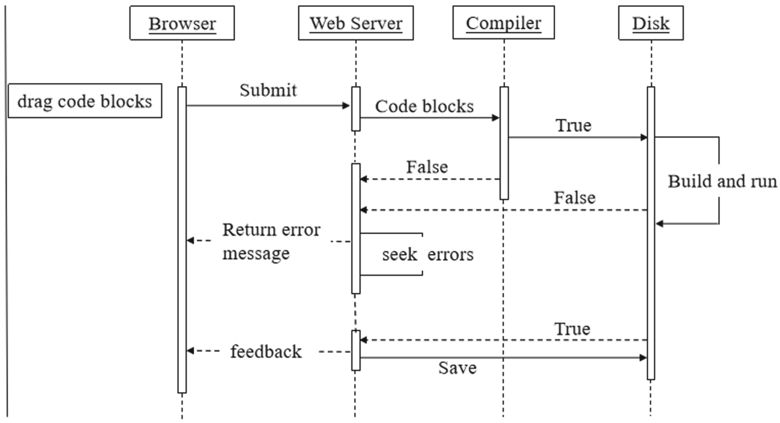


Fig. 4. Overall algorithm timing diagram.

and the system will adjust according to the current student's completion: if there are remaining distractors, will remove one; if there are no more distractor, will combine two code blocks that belong to the upper and lower positions in the correct code order into one block, so that there is one less code block that students need to restore the order. The difficulty adaptation mechanism in the question mainly reduces the difficulty of the exercise by removing the distractors and merging the blocks. At the same time, in order to prevent students from pressing the help button directly to seek help, the platform sets the trigger conditions of the help button: only after submitting three different error results, the help button can be clicked, which can effectively avoid students simply rely on help to learn to learn.

Adaptive difficulty between questions: Difficulty adaptation between questions adjusts the difficulty of the next question by analyzing students' comprehensive exercise-making behavior as feedback. For example, a student completes the question after trying multiple times on Exercise 1 or clicking the help button multiple times, which means that the student has greater resistance when completing the question, then the next question system will select a question with a lower difficulty factor to avoid he be discouraged from learning because of too much resistance to practice. If a student succeeds with a few consecutive attempts, it means that the student has a good grasp of knowledge, and the system will select a question with a higher degree of difficulty when choosing the next question to improve the student's knowledge mastery level. The difficulty of adaptation between questions is mainly achieved by recording the data of students to complete a single exercise and analysis to obtain the difficulty of the question to the students. It can effectively adjust the difficulty of the next problem according to the actual difficulties of the students.

4 Running Instance

4.1 Basic Exercises

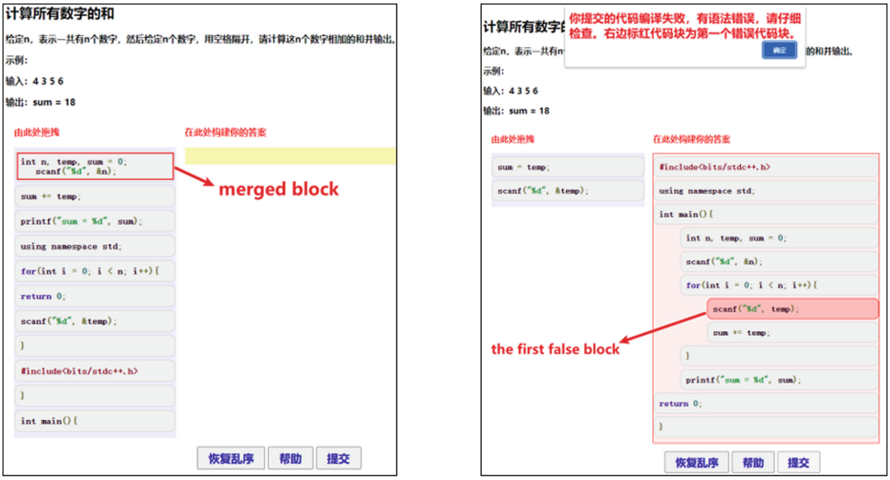
The learning platform provides Parsons problems which are drag-and-drop practice exercises. This exercise method is a typical Parson problems practice. Students only need to identify the correct error blocks and adjust the order of code blocks to arrange and indentation positions to complete the exercise. As shown in Fig. 2, the topic description is displayed at the top of the browser interface, and an input and output test example is given for students' reference. The left box at the bottom of the interface is the provided out-of-order code blocks, which includes all needed code blocks and distractors. Students need to drag and drop the code blocks in this area to the right box to sort them, so that the last right code blocks can solve the current problem. At the same time, the indentation of each code block must be correct, otherwise an error will be prompted. Figure 5(a) shows an exercise in progress.

4.2 Adaptive Difficulty in Practice

During the exercise, the Parsons problem can adjust the difficulty of students to adjust the difficulties according to the feedback of students to help students learn better. When students think that the current question cannot be completed by themselves, they can click the help button to reduce the difficulty of the question. There are two ways to reduce the difficulty, including removing distractors and merging sequential code blocks. The first choice of removing distract blocks is to remove the distract blocks that move to the right area, because it means that the student did not distinguish that the block was wrong, and the second choice is to remove the distract block in the left area. As shown in Fig. 5(b), it is the result of the operation of removing the distractor, the right side is the initial candidate code blocks, the left side is the candidate code blocks with one distractor removed, and the code block in the red box on the right side is removed. If the distract blocks in this question are all removed, then the difficulty will be reduced by merging code blocks. The merged two code blocks will be one. The merged code block is shown in Fig. 6(a), the red box in this figure is the block after merging two code blocks in the correct order. Through these two methods, adaptation of the difficulty of the questions can effectively reduce the difficulty of the questions.

(a) An exercise in progress (b) Removed distractor

Fig. 5. An exercise in progress (a), Removed distractor (b).



(a) Merged two code blocks (b) Wrong result with syntax error

Fig. 6. Merged two code blocks (a), Wrong result with syntax error (b).

4.3 Feedback After Practice Submission

According to the different results submitted by the students, the platform has different prompts. The focus is on the error prompt. Because there are many errors, according to the reasons, the platform will have detailed prompts for reference and correction. When students complete the code drag and drop, they need to click the submit button to verify that if it is correct. After clicking submit, there will be feedback prompting students with errors or pass. There are two types of error results. One is that the order of the code submitted by the student fails to compile in the background, which indicates that the code has a syntax error, that is, the student's answer selects a code block with a syntax error, and the interface will prompt that the program has a syntax error, please check again, at the same time, the first error block of the student code block will be marked. As shown in Fig. 6(b), the code block marked in red is the first error position. The another error result is that the student's submits code compiles successful in the background, but the output result is wrong, which indicates that there is a logical error in the student's code blocks. As shown in Fig. 7(a), the interface will prompt that the program output result is wrong, please check again, and the wrong result and correct result will be provided for students' reference. If the program compiles and the output is correct, it will prompt the question passed and then will jump to the next question, as shown in Fig. 7(b).

(a) Wrong result with logic error (b) Commit passed

Fig. 7. Wrong result with logic error (a), Commit passed (b).

5 Summary

This paper combines the current teaching needs of domestic C programming courses, examines the research and needs of programming language teaching methods and platforms at home and abroad, and designs a C learning platform based on Parsons problems. The platform breaks through the design of the pure code writing learning method of the previous platform which brings a high cognitive load learning experience to C novices, helps novices learn the basic knowledge of C more efficiently in a way of low cognitive load.

In the C learning platform designed based on Parsons problems in this paper, students only need to simply drag and drop to complete the exercises, which avoids the problem that novices make frequent easy mistakes in the process of write code due to lack of basic knowledge, which leads to the frustration of learning confidence, while adding distractors enables students to more effectively recognize common programming errors and firmly grasp the basics. The platform of this paper also realizes that the system automatically adjusts the difficulty of the exercises according to the feedback of the students' behavior through the adaptive difficulty mechanism, the difficulty of the exercises can be more in line with the knowledge level of the students, so that each student can learn the C more easily and efficiently, thereby building up students' confidence in learning programming languages, which is very helpful for their future learning.

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Investigation and Study of Teachers' Teaching Development Centers in Higher Institutions in Hunan Province

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Abstract. In recent years, colleges and universities in Hunan Province have set up teachers' teaching development centers. In order to deeply understand their organizational structure and work situation, a questionnaire survey was conducted on the staff of teaching development institutions of ordinary colleges and universities in Hunan Province. According to the survey, the work of teaching development centers in Hunan Province has been widely recognized by the majority of teachers, but there are still problems such as imperfect organization, inadequate condition construction and lacking of academic professionalism. The solution of these problems requires the university to put forward the understanding and top-level design at the school level, strengthen the centers' cooperation and exchanges between different colleges and universities, and jointly promote the level of teaching quality and faculty development.

Keywords: teachers' teaching development center · questionnaire survey · higher education

1 Background

In the year of 2011, the Ministry of Education promulgated the Notice of Construction of National Teachers' Teaching Development Demonstration Center (No.107, 2012), which officially opened the construction of teaching development center of higher institutions in China. Since 2011, Xiamen University, Sichuan University, Dalian University of Technology, Zhejiang University and Fudan University successively set up centers. In September 2012, the Ministry of Education selected 30 national teachers' teaching development demonstration centers including Xiamen University. Since then, colleges and universities across the country have started the construction of centers, and the center has gradually become an important force in serving the teaching development of teachers in colleges and universities. At the same time, The State Council and the Ministry of Education have issued a number of documents related to teaching in higher education, repeatedly emphasizing the construction of teacher teaching development centers and the improvement of teachers' teaching ability. In January 2018, the CPC Central Committee and The State Council issued the Opinions on Comprehensively Deepening the

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Reform of Teacher Team Construction in the New Era, requiring the establishment of a school-level teacher development platform and the comprehensive training of teachers' teaching ability improvement in institutions of higher learning. In September 2018, the Ministry of Education on speed up the construction of high level undergraduate education comprehensively improve talent training ability opinions (2,2018, also known as the new era of article 40), in October 2019, the Ministry of Education issued on deepening the reform of undergraduate education teaching comprehensively improve the quality of talent training opinions (2019, 6), are to strengthen the construction of college teachers teaching development center put forward clear requirements.

Compared with the east China [1], central China, southwest China and northeast China, where the national teachers' teaching development demonstration centers are relatively concentrated, the overall construction of the teaching centers in Hunan Province has developed a little later. In recent year, with the continuous improvement of the quantity and quality of teachers in higher institutions in Hunan Province, the elevation of teachers' teaching ability has attracted great attention from colleges and universities in Hunan province. The Department of Education of Hunan Province promotes various measures to develop the teaching ability by organizing teaching competitions for university teachers, selecting outstanding teachers and setting up special projects for teaching research and teaching reform. In order to better understand the current situation of teaching development centers in colleges and universities in Hunan Province, find out the problems existing in the current teaching development work, and explore the effective path of the construction and promotion of teaching development center, this paper carries out the research work of teachers' (teaching) development center in higher institutions in Hunan Province. Hereafter, the teachers' teaching center is shortened to teaching center in this article for convenience.

2 Survey Design and Implementation

The research was carried out in the form of questionnaire survey and network survey. The questionnaire included two sets of questionnaires for full-time staff of teaching center (real-name questionnaire) and front-line teachers (anonymous questionnaire). Network research is carried out through websites.

The questionnaire for the full-time staff of the organization includes the organization system, responsibility positioning, operation effect and difficulties of teaching center.

The questionnaire for front-line teachers includes the basic information of teachers (gender, professional title, teaching age, etc.), participation in the activities of the teaching center, satisfaction with the teaching center and activities.

The questionnaire survey was carried out through online questionnaire platform in May 2020, with 57 questionnaires for full-time staff of the center, 33 valid questionnaires (one for one school), 9407 questionnaires for frontline teachers, coming from 36 colleges and universities.

3 Survey Results and Analysis

3.1 Setting Status of the Teaching Center

A) Set Time. Among the 33 valid questionnaires for the full-time staff of teaching center, two universities replied that they had not yet set up teacher (teaching) development centers. Among the other 31 universities, the first one university set up teaching centers in 2013, and 18 universities respectively established teaching centers in 2016–2018 respectively, showing a concentrated growth trend. In 2020, another 5 universities established teaching centers. In general, teaching centers of various universities in Hunan province were established for a short time and are still in the early stage of institutional development (Fig. 1).

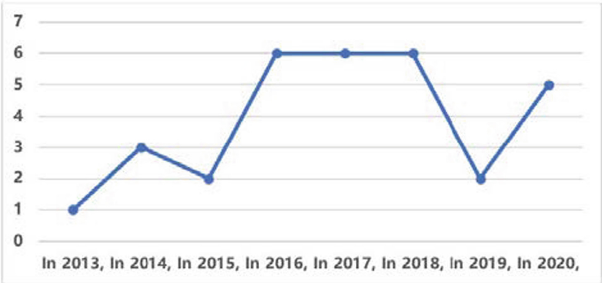

Fig. 1 The establishment year of teaching centers in colleges and universities in Hunan

b) Staff Composition. According to the number of staff and the actual number of full-time members, 13 teaching centers are in the state of understaffed, and 74.2% center staff is below 3 members, as shown in Fig. 2.

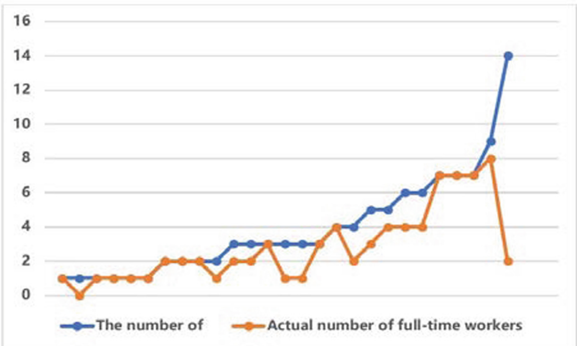

Fig. 2. Number of full-time staff members and the actual working number of teaching center

c) Major Responsibilities. There are 25 teaching centers which proclaim their positioning as: a service organization with administrative functions. There are 4 teaching centers positioned as administrative institutions, and 2 centers positioned as academic service institutions.

According to the investigation of the responsibilities of teaching centers, most of them have the function of teachers' teaching ability development, and some centers undertake the functions of scientific research ability development, teaching quality monitoring and evaluation and certification. By comparing the functions of the center, centers affiliated to the personnel department pay more attention to the function of supporting teachers' career development, while centers affiliated to education department focus more on teaching ability development, and some of them, have teaching quality monitoring and evaluation functions. There are also some centers affiliated to the personnel department following the original teacher management and training functions, only including pre-job training and exchange designation related functions.

The questionnaire also lists 17 specific tasks [2], five satisfaction options from extremely satisfied to completely dissatisfied, and one "no experience" option. According to the answers, there is 64.5% of the centers did not carry out the TA training, 38.7% of the centers did not have the function of teaching resource construction, and 29% of the centers, did not proceed international teaching ability improvement, training team construction and curriculum evaluation.

d) Main Difficulties and Obstacles. In order to further understand the main obstacles and problems existing in each center, the questionnaire set up a question "What are the biggest difficulties in the work of the teaching center".

Among 33 pieces of answer to this question, the expressions are relatively focused on the flowing aspects: lack of staffing, imperfect operation mechanism, insufficient funds, no exclusive training site and lack of experienced trainers, as shown in Table 1.

Table 1. Statistical table of main difficulties faced by teaching center.

Main opinion	Insufficient full-time staff	Imperfect operation mechanism	Insufficient funds	No exclusive training site	Insufficient trainers
Frequency of similar expressions	17	9	9	5	4

3.2 Operation Situation of the Teaching Center

The operation situation of teaching centers is mainly analyzed by collecting and sorting out the questionnaires of front-line teachers in colleges and universities. This part of questionnaire aims to obtain two aspects of information, including participation & motivation, satisfaction & interests.

a) Participation and Motivation in the Activities Organized by the Teaching Center. As for the participation, 75.5% teachers have heard of the teaching center in their institutions and 62% have taken part in the activities. The result indicates that the teaching centers have done a certain level of publicity to help most instructors know about the Centre, but it should be further enhanced.

As shown in Fig. 3, it illustrated that for those 5800 respondents who participated in the activities, the principal reason is self-improvement of instruction, and the second one is promotion of personal profession. And an attractive marketing also played a certain role. About 16% of the respondents were required by their universities because of compulsory regulation.

Fig. 3. Main reasons of participating activities organized by teaching center

When we go further of the purposes of all the respondents, it showed that the most 3 important motivations are: to improve their teaching ability, to learn educational theories thoroughly, and to improve academic abilities, as shown in Fig. 4.

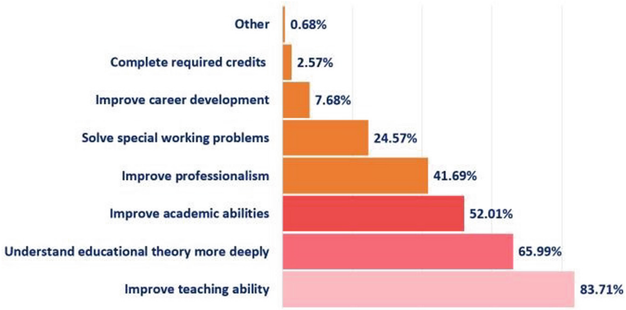

Fig. 4. Main motivations of participating activities organized by teaching center

Then comes to the experience. As can be seen from Fig. 5, one important finding is that most teachers did gain from training activities but still find implementation challenging, which suggests that further attention of implementation practice is required.

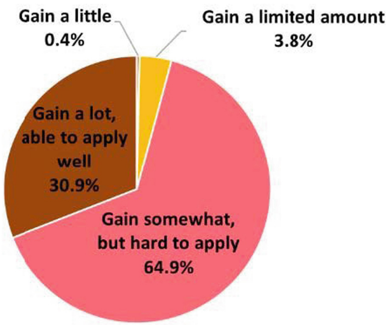

Fig. 5. Teachers' feelings after participating in the activities

b) Satisfaction and Interests in the Activities and Teaching Center. There are three questions in this dimension, including: the overall evaluation of the center, the evaluation of all aspects of activities, and the theme of activities that teachers are interested in.

In order to obtain comprehensive feedback on satisfaction of the teaching center, the question is asked from two aspects, one is the feeling of each participant himself/herself, the other is the observation of his/her colleagues.

According to the survey, for the question, "How do you feel about the FD Centre at your institution?". 58.07% of teachers involved in the survey were extremely satisfied and satisfied with their teaching center, and 22.21% of other teachers were rated as "neutral".

As for the question, "What do you think of your colleagues' feelings regarding the teaching center at your institution?", the teachers involved gave very similar choice compare to their own satisfaction. From Fig. 6, 15.43% of teachers thought that their colleagues feel extremely satisfied with the work of the teaching center, a little bit lower than their own satisfaction, and 23.72% chose "not sure", lightly higher than their aspects, other choices are similar. In general, the work of the teaching center has been widely accepted by the teachers.

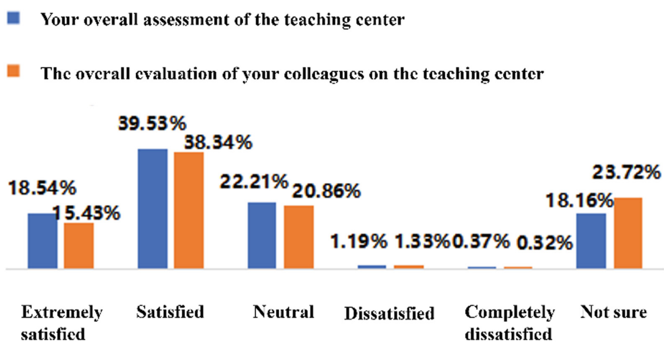

Fig. 6. Teachers' satisfaction with the teaching center

In order to obtain further information of the satisfaction of participates to those training activities organized by the teaching center, the questionnaire set up questions from 6 parts to get the feedback, including the "overall service attitude" and "overall service level" of the center's faculty members, as well as the "effect", "applicability", "attraction" and "promotion "of the training activities. As illustrated in Fig. 7, more than 65 percent of teachers chose "extremely satisfied" and "satisfied" for each question. And very small part of participants chose "dissatisfied". It can be seen that teachers of each school highly approve the activities of the teaching center as the whole. Of course, there is still room for improvement.

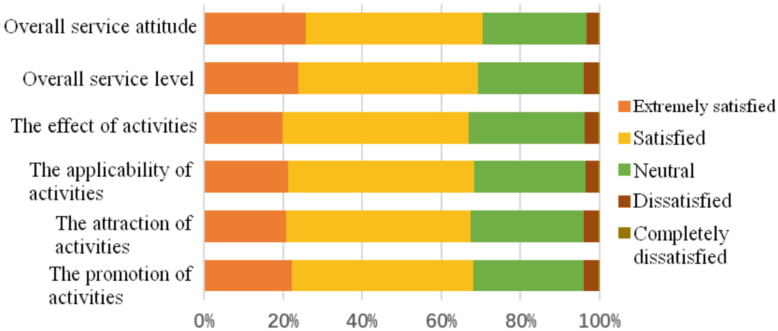

Fig. 7. Teachers' satisfaction with the activities held by the teaching center of our school

The last question is about the expectation and interests of the teachers for the teaching centers' events. As illustrated in Fig. 8, it shows that most of the themes meets the requirement of the instructors, especially the instructional design and strategy. In general, the theme of "instructional design" is the most popular among teachers, reaching 5,729 people, accounting for 60.83% of the total, followed by "instructional strategy", accounting for 58.75%, "modern educational technology", accounting for 53.98%, and "Construction and use of MOOC", accounting for 53.41%.

Generally speaking, the interests and demands of different instructors might be different, especially with different teaching experience. In order to have a more detailed understanding of teachers' demands on training events, we made a cross-analysis between the interested activity themes and the years of teaching experience (as shown in Fig. 9). It is interesting to notice that the difference of different groups in some themes is larger than others. That is to say, for some events, teachers with different teaching experience (or different career periods) have different demands. For the others, the demands are close. For example, young teachers or teachers with shorter teaching experience have a relatively lower demand for modern educational technology, which is supposed to be familiar in their early learning and life experience. While another theme, training for teaching competition, the distribution shows an almost opposite trend, which can be easily explained as that the willing of younger teachers taking part in the teaching competition is higher than that of older ones. As for the theme of instructional design, different age groups of

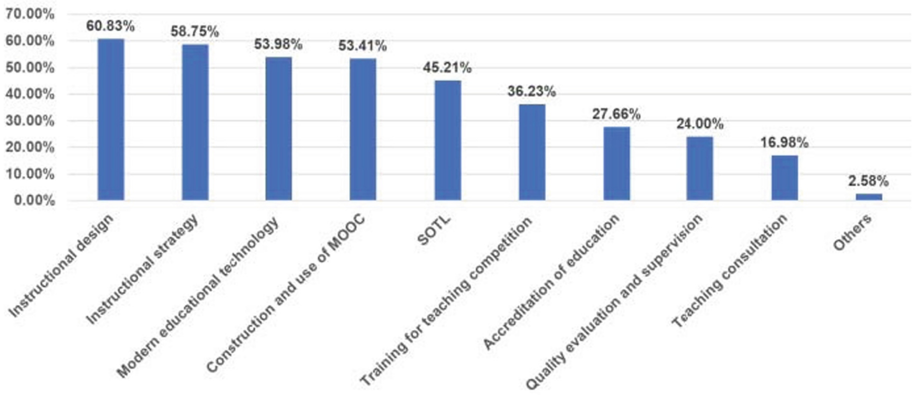

Fig. 8. Most expected themes of teaching center activities

teachers gave close frequency of choice, about 60%, which indicates that this theme is needed by most teachers from young to old.

Sub-questions	5 years and below	6-10 years	11-15 years	16-20 years	More than 20 years
Modern educational technology	1073 (43.3%)	830 (51.6%)	1095 (59.6%)	870 (57.7%)	1216 (61.3%)
Instructional design	1526 (61.6%)	982 (61.1%)	1125 (61.2%)	902 (59.8%)	1194 (60.2%)
Instructional strategy	1450 (58.5%)	962 (59.8%)	1063 (57.8%)	874 (57.9%)	1184 (59.6%)
Construction and use of MOOC	1280 (51.7%)	883 (54.9%)	1054 (57.3%)	809 (53.6%)	1004 (50.6%)
SOTL	1149 (46.4%)	826 (51.4%)	896 (48.7%)	686 (45.5%)	701 (35.3%)
Accreditation of education	757 (30.5%)	475 (29.5%)	531 (28.9%)	420 (27.8%)	422 (21.3%)
Quality evaluation and supervision	575 (23.2%)	350 (21.8%)	409 (22.3%)	328 (21.7%)	598 (30.1%)
Training for teaching competition	948 (38.3%)	731 (45.5%)	702 (38.2%)	538 (35.7%)	493 (24.8%)
Teaching consultation	467 (18.8%)	285 (17.7%)	280 (15.2%)	241 (16.0%)	326 (16.4%)
Others	56 (2.3%)	30 (1.9%)	38 (2.1%)	43 (2.8%)	76 (3.8%)

Fig. 9. Different interests on activity themes from teachers with different teaching experience

According to the survey results, it is very clear that almost all the given activities are required by teachers. But there are still some activities, such as SOTL (Scholarship of Teaching and Learning) and teaching consultation that are not well-known by participants, although they are quite helpful for the improvement of teachers' teaching quality.

The results also suggest that the teaching center should carry out various types of activities, and expand the range of activity theme continuously. At the same time, each activity should meet the demands of teachers at different stages of career development, which means the demands of teachers should be analyzed in advance, especially considering of the teaching experience, scientific research experience and comprehensive capacity.

4 Conclusion

According to the survey results, most colleges and universities in Hunan province have set up teaching center, but with short established time, generally in the early stage of institutional development. The organization, functional duties and operation mode for each center has great differences. Many centers also face series of difficulties in the organization building, team building and mechanism construction. However, as an emerging organization of colleges and universities, the work and activities of each teaching center has been widely recognized by the teachers in the university. Most of the teachers feel satisfied with the teaching centers which provide support for their teaching ability improvement in various aspects. Nevertheless, the difficulties and existing problems faced by the teaching centers cannot be ignored. If not solved, these problems might affect the subsequent high-quality development, and even influence the existence of the centers.

4.1 The Organization is not Sound

The duties are not clear. Based on the spirit of document No.107 [2012], the six basic functions of the teaching center are teachers' training, teaching consultation, teaching reform research, teaching quality evaluation, quality teaching service, demonstration and leading role. But in fact, due to the different understanding and attention of teaching centers, there are great differences in institutional setting, the functions of some centers are not complete, the duties are not clear, some centers are not fully run, and even difficult to carry out their work.

Lacking of full-time staff. The staff set for centers are generally low, and nearly half of the centers are understaffed. Some centers, which affiliated to a functional department, basically run the two-person mode, "center director + training section chief", and often part-time for many other jobs. Some centers seem to have a large staffing, but in fact they still have the functions of quality monitoring and evaluation and modern educational technology, with the limited full-time staff to really carry out teaching development.

Funding is tight. Most centers have set up special funds, but limited and dependent. Due to the functional division is not clear, the budget, allocation and use of funds are restricted. Some of the center director, cannot get the actual financial signature right, thus the special funds are difficult applied to special events.

4.2 Conditional Construction is not Sufficient

The results of questionnaire survey show that the construction of teaching trainers and training space in teaching center is not sufficient.

Lacking of trainers, especially education expert teams, is a common problem faced by all centers at the present stage. The staff of teaching center often lack of education background. The mechanism of attracting and cultivating the front-line teachers to become education experts has not yet complete. These problems make it difficult to carry out in-depth theoretical research on the field of teacher development, education theory and curriculum construction, etc.

The construction of training space mainly includes two aspects: physical space and cyber space construction. As for the physical space, from the survey, there are about 10 centers have fixed room of more than 100 square meters (including at least one training classroom), and most of the centers were carried out in non-fixed and non-proprietary sites. The construction of cyber space includes center website, WeChat public account, online training management platform, etc. Only 11 centers in the surveyed universities have built proprietary portal site, two centers' websites include training management platform; two centers have independent WeChat public account.

4.3 Academic Professionalism is not Strong

In addition to the above-mentioned problem of insufficient professional construction of trainers, the deeper problem is the positioning of centers in the universities. In the surveyed centers, only two teaching centers are positioned as academic service institutions. The functions of some centers are originally divided from the personnel division or the education department, inheriting the administrative management mode. Centers' teaching ability improvement activities are usually implemented through administrative instructions. Through the investigation, it is also found that some important duties, treated as an important work to promote the student-centered conception in foreign universities, including graduate teaching assistant training, teaching consultation, resource construction and other work, are still quite missing in the responsibilities of teaching centers in Hunan province.

The positioning and management mode of the center reflects from a certain level that the school and the head of the center do not have an adequate understanding of the professional development and academic development value that the center should carry. Teachers (teaching) development center was set up to help teachers transforming from experience development mode to professional development mode. From the point of centers' function, the center should have the nature of specialized and academic, and play a leading role in teaching. The center should become the base of solving teaching problems and difficulties, researching on teaching theory, methods and technology, cultivating teaching culture, promoting the continuous improvement of teaching quality. Simply equate the teaching center with the general administrative agency runs counter to the purpose of its establishment [3].

5 Suggestions

Under the vigorous promotion of the Ministry of Education, colleges and universities have set up teaching centers in the past decade, which should be said to be the gratifying first step. The next step should focus on the connotation construction, so that the center can play an important role in promoting the higher education from scale development to high quality development. From the purpose of setting up teaching center, the key work is to provide support for teachers' professional development, various forms of teaching training activities, which carry the propaganda education teaching science, implement the "student-centered" concept, promote teaching reform and innovation, achieve teaching academic community goals and tasks. The final purpose is to innovate teachers' teaching and students' learning paradigm, adapting to the transformation of the new era of higher education reform and development requirements [4].

First of all, from the school level, it's very important to strengthen the top design and clear the positioning and work functions of the teaching center. In order to make sure of centers run effectively, measures such as strengthening the organization construction and staffing, investing proprietary funds and site, should be implemented. These measures are also the needs of teachers to realize the transformation to professional development mode, and also the needs of high-quality development of school education.

Secondly, at the level of teaching center, facing with new working methods and new requirements, the center staff should have the courage to accept challenges, make breakthroughs and innovate, and actively think about the future development of the center. As an organization with both administrative functions and academic service functions [5], the most important capability is to apply the management function to mobilize various resources, then provide sufficient services and support for the development of teachers. From the perspective of external function, the center should strengthen the linkage with superior departments, brother universities and even related enterprises to provide sufficient external impetus. From the perspective of internal function, the center should promote the driving force of grass-roots teaching organization, cooperation with personnel department, as well as education department and other administerial departments. The development of the center cannot be separated from the construction of the center members and the part-time trainer team. The work of the center is academic, and the service of the center should be professional. In view of the fact that most members of teaching centers in universities do not have education-related professional background, it is more necessary to improve the professional level and academic service quality through continuous learning. At the same time, the center should create a good atmosphere to absorb and cultivate a certain number of teaching experts and teaching development experts. Meanwhile, specialized professional and academic research projects can also support and guarantee the sustainable development of the center.

Third, teaching centers of colleges and universities should strengthen cooperation and exchanges to realize resource sharing, complementary advantages, mutual promotion and overall improvement. Cooperation is win-win, and the overall situation is stronger [6]. Many regions, including Shandong, Zhejiang, Jiangsu, Anhui and Hubei, have set up provincial teaching center alliance. Under the advancement of China's higher education society, the northwest and northeast China also formed a teachers' teaching development research institute, with the architecture of research, consulting and training system. No matter which form of cooperation, sufficient cooperation and exchange can not only solve the problem of resource shortage of new institutions, strengthen the academic development and professional development of the center, but also promote the rapid growth and benign growth of teaching center [7].

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Predicting Students Performance in SPOC-Based Blended Learning

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Abstract. The small private online course (SPOC)-based blended learning is becoming increasingly significant for college campus courses in the current COVID-19 pandemic scenario. It is critical to predicting students' performance for providing personalized intervention and guidance in the blended learning environment, however, it has been shown in few studies that learning performance is predicable in situations related to teaching context. In this paper, we implemented one whole semester blended learning course based on Xuexitong and traditional classroom to examine the predictability of student performance. Multiple linear regression model was utilized to analyze the impact of online and offline learning activities on student performance. Nonlinear models including GBDT, SVR and KNN were contrasted to check whether the predictions were generalized. The experiment reveals that learning data from off line and online activities that are part of blended learning can be used to predict students' performance. The attributes that influence most in our course were Class. Attendance, Online. Task, Lab.Projects Score, Online. Time and Online. Peer-review Grade. The results can help to learn about students learning situations and provide personalized intervention.

Keywords: Small private online course (SPOC) · Blended learning · Learning activities · Students performance prediction

1 Introduction

Blended learning refers to learning involving both face-to-face classroom and online learning [1]. Its aims to eliminate the drawbacks of conventional classroom methods and pure online learning [2]. According to Horizon Report in Higher Education [3], There are growing blended learning courses that are becoming increasingly significant, with information and communication technologies (ICTs) being developed to complement, not replace traditional forms of learning especially in the current COVID-19 pandemic scenario. The Small private online course (SPOC) aims to provide small-class teaching and compared with Massive Open online course (MOOC), is more suitable for further teaching professional knowledge and personalized teaching exploration for localized campus credit courses [4]. Recently popularity of SPOC-based blended learning has

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grown and there are some practices that have achieved good results, such as Embryology set up by Guo [5] and Physiology by Zhang [6].

SPOC-based blended learning environments gather much data about students' learning activities in traditional classrooms and online environments. How to use this information to predict student learning achievement has been an important concern in learning analysis. Students' performance in blended learning has been studied in some studies. Chango et al. [7] developed a data fusion and mining model to predict whether a student can pass the final grade in a blended environment, providing insight into student performance prediction in blended learning based on SPOC platform. Students' weekly test pass was predicted using logical regression by Wan et al. [8]. In a study by Yu et al. [9], a linear regression model and a deep learning model were developed to predict student performance in SPOCs. The majority of these studies, however, tend to ignore the teaching context and focus instead on predictability of student performance [10]. Due to the varied types of blended learning [2] and the data-driven predictions, it is not possible to predict student performance without a specific context [11]. The relationship between learning activities and learning performance is rather crucial for teachers to be able to provide personalized intervention and guidance to their students.

In order to solve the above issue, in this study, we built a blended learning course *Computational Thinking* by *Xuexitong* (one SPOC learning management platform launched by Superstar Group) and a traditional classroom to explore the possibility of using learning activities in a blended environment to predict student performance. Students' learning behaviors within the teaching context were analyzed using a white box model multiple linear regression. The generalization of the predictions was evaluated using nonlinear models, including GBDT, SVR, and KNN.

Following the introduction, the design of SPOC-based blend learning implemented in our study is described in Sect. 2. The description of data collection and data preprocessing are depicted in Sect. 3. Section 4 presents detailed data analysis and learning performance prediction. Finally, the conclusion and some future works are given in Sect. 5.

2 Design of SPOC-Based Blended Learning

As blended learning is highly context-dependent [12], for the later learning analysis, it is important to have an understanding of the teaching content. This section describes how blended learning was designed and implemented in this study. To achieve the deep integration of online and offline learning, the blended environment is composed of three parts: pre-class, in-class and after-class, and various online and offline activities were designed as shown in Fig. 1.

In the pre-class, students were required to learn autonomously on the *Xuexitong*-based course site (only available for learners enrolled in the course). The course videos can be viewed in advance by the students according to learning tasks published by teacher, taking choice tests to check their understanding or discussing with peers in the forum and interacting with the teacher online. Students can be free to choose any time and location to explore the online course.

In the class, the teacher and students met in an offline classroom and Laboratory every week at a fixed time required by the course schedule. In response to students' learning situations, the teacher taught key and difficult knowledge points using projectors/whiteboards/blackboards and used *Xuexitong*' tools to conduct roll calls at random. Students were encouraged to voice their ideas or express their opinions. They can discuss with peers and teachers, do exercise, practice Lab subjects and projects, participate in group activity through Xuexitong. A seamless connection between online and offline learning was achieved through classroom instruction.

Students were encouraged to participate in after-class activities to help them digest, consolidate, and test the material they had learned in class. Choice questions and peer-review assignments associated with teaching contents were deployed on the course platform. All learning materials were uploaded to course site by the teacher in advance. These after-class assignments allow students to selectively review videos, read textbooks or consult other relevant materials as needed.

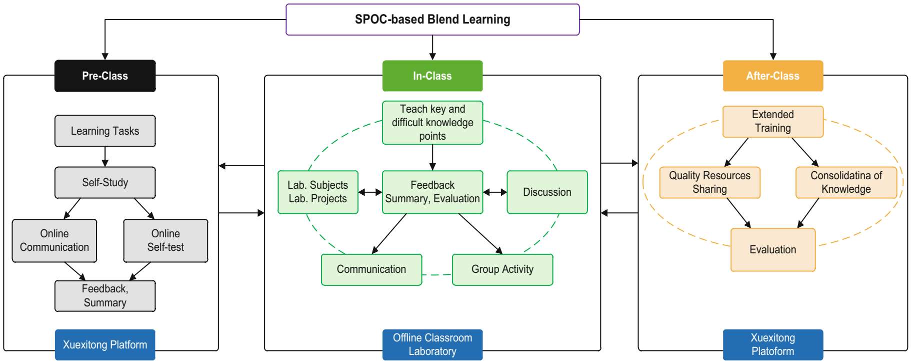

Fig. 1. The design of learning activities in SPOC-based Blended learning

3 Data Collection and Preprocessing

3.1 Data Collection

We launched the undergraduate-level Computational thinking during the first semester of the academic year 2021–2022 and 109 first-year civil engineering students from Southwest University, China enrolled in the course. The course contains ten units of teaching content and was implemented by *Xuexitong*-based blended learning according to the above methods. This research followed the ethical, legal requirements of the university's research ethics committee. All the students were well-informed and agreed to participate in the experiments reported in this study. The SPOC course site interface was shown in Fig. 2. A final exam was given offline at the end of the semester and final grades were recorded to measure the performance of the students.

(1) Offline learning data collection

Offline learning includes traditional face-to-face classroom and laboratory. We collected the following information during the course's 15 theory classes and 10 laboratory sessions:

Fig. 2. The site interface of *Xuexitong*-based blended *computing thinking* course

- Classroom. Attendance (Cla.Att): It was obtained from singing statistics sheet recorded in *Xuexitong* used to monitor each time's attendance. If a student attended a session, the value was 1, otherwise it was 0
- Classroom. Activity Performance (Cla.ActPer): In each of the five group activities, the teacher graded each student's score. The value ranged from 0 to100.
- Lab.Subjects Score (Lab.SubSco): For each of the 7 practical subjects, this is what each student scored in each subject, graded by the teacher. The value ranged from 0 to 100.
- Lab.Projects Score (Lab.PrjSco): In each of the 3 course projects, the teacher graded each student's score from each practical project. The value ranged from 0 and 100.

(2) Online learning data collection

Throughout the semester, *Xuexitong* recorded students online learning behaviors. We used the tool called one-click export to download the log statistics from the course site. As *Xuexitong* does not support recording all online behavioral data, for the practicability of the study, we selected some general behaviors about student interaction with the online course from log statistics and this information is described as follows:

- Online. Task: There was a specific percentage of tasks each student was expected to complete on the course website. Students were asked to complete 70 compulsory tasks and 37 optional tasks. The value ranged from 0 to 1.
- Online. DiscussBoard: This was the number of contributions/actions made by students to the discussion board, including the number of posts, replies and the liked. It ranged from 0 to a maximum value provided by the most active student on the board.
- Online. Time&Page Views: These include the total time that each student spends watching learning videos on course site and the total views that each student visits learning pages throughout the whole semester. The value of time ranged from 0 to the

time spent by the student who spend the most time connected to the platform. The counts of page views ranged from 0 to the biggest views calculated by the student who visit unit learning pages.

- Online. Quiz: These include the students' choices questions scores (CQS) obtained in *Xuexitong* choice test set by the teacher and peer-review assignments grades (PR. Grade). Each student was requested to complete 8 choices questions tests and 3 peer-review assignments. To facilitate behavior analysis, the following average values were calculated for each student:

$$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{1}$$

Where x_i represents the score of each test or assignment and the variable of n represents the required number of tests or assignments.

(3) Final exam
All students must take part in final exam at the end of the course. The exam includes two parts: a theory part with 30 questions (20 single choices, 10 TF questions) and a practical part with 4 operational problems. The exam was fully computer-based, requiring the students to complete in 2 h. The final score was given by computer grading and was the sum of the scores in each part, which ranged from 0 to 100.

3.2 Data Preprocessing

Total 12 learning attributes including 4 offline activities data and 8 online activities data as well final exam scores of 109 students were collected. In order to keep the same fundamental unit, all data were normalized to the interval [0, 1] by the min-max normalization. The formula is as follows:

$$x_{norm} = \frac{x - min(x)}{max(x) - min(x)} \tag{2}$$

Where x_{norm} is the normalized value, max(x) and min(x) represents maximum and minimum value of x, x is the original value.

4 Data Analysis and Learning Performance Prediction

4.1 Data Analysis

We used correlation analysis to investigate the relationship between student activities and learning performance [13, 14]. The Person coefficient was calculated as shown in heatmap of Fig. 3.

It can be seen that all learning activities were positively correlated with the final grade. The relationships between Cla. Att, Lab.PrjSco, Online. Task and the final grade have a

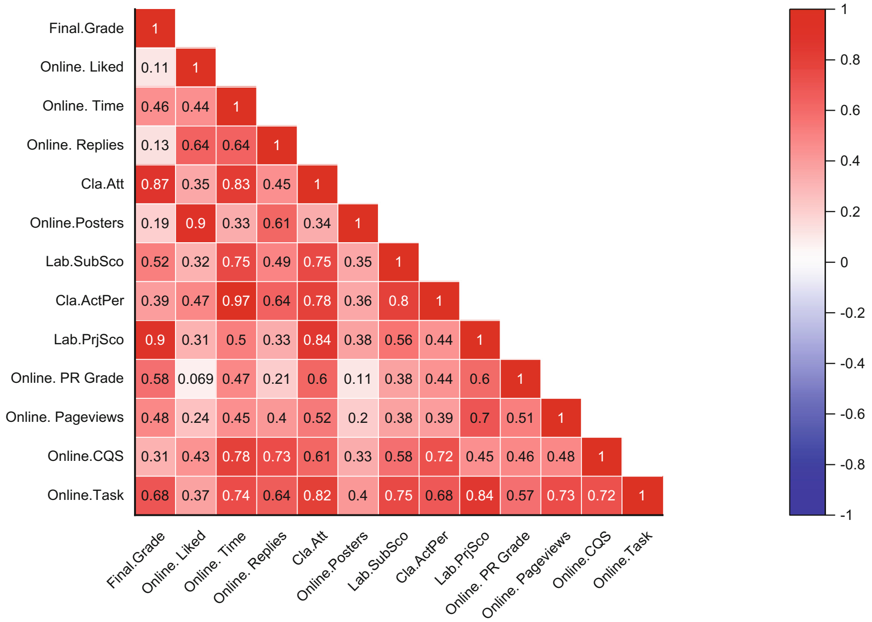

Fig. 3. Correlation between learning activities and final grade

strong correlation and the Pearson Coefficients of these three are bigger than 0.6. The result indicates that the students who regularly attended offline classes, exhibited high performance in Lab projects and completed a high number of tasks in SPOC platform are likely to achieve better academic performance. It also can be observed that Online. Time, Online. Pageviews and Online. Peer-review Grade as well as Lab.SubSco had positive effects on student performance with medium correlation [0.4, 0.6], indicating that the more time spend on watching leaning videos and learning pages, the higher score in peer-review and lab subjects, the better student academic performance might be. Meanwhile we also notice that the activities of online forums including posting, replying and liking have very weak correlation with final student academic performance. It might due to the fact that in this course students were still used to consult with teacher or peers via IM tool QQ, which led to low forum activities participation.

4.2 Learning Performance Prediction

The variance inflation factor (VIF) of each attribute was calculated as shown in Table 1. It can be seen that each VIF value was lower than 5, indicating no severe multicollinearity between the learning activities. As there was no multicollinearity between the attributes and student performance, all attributes were included in the prediction. A multiple linear regression with forwarding selection using ordinary least squares (OLSs) was used to determine each attribute's coefficient, whose significance was tested using a student t-test. Table 1 shows the Pearson correlation analysis of the variables.

Table 1. Pearson correlation analysis between the variables and the final grade

Attributes	VIF	Coefficient	Std err	*p* value
Cla.Att	1.437	0.2531	0.037	0.005
Cla.ActPer	2.765	\	\	\
Lab.SubSco	1.581	−0.1725	0.255	0.171
Lab.PrjSco	3.011	0.5123	0.126	0.002
Online. Task	1.295	0.3246	0.068	0.021
Online. Posters	2.287	\	\	\
Online. Replies	2.321	\	\	\
Online. Liked	3.031	\	\	\
Online. Time	1.997	0.2634	0.051	0.001
Online.Pageviews	1.451	0.0827	0.154	0.081
Online.CQS	3.557	\	\	\
Online. PR Grade	1.681	0.2341	0.065	0.002
Constant	\	0.2351	0.151	0.000
R^2: 0.661 Adjusted R^2:0.601				

* std err: the standard error of the coefficient.
* coefficient: linear model coefficient.
* p values: Generally, $p < 0.05$ means a statistical difference, $p < 0.01$ means a significant statistical difference, $p < 0.001$ means an extremely significant statistical difference.

In order to evaluate the goodness of the fit of the prediction model, we choose R-square (R^2) and adjusted R-square (R^2) as evaluation metrics. The formulas are represented as follows:

$$R^2 = 1 - \frac{\sum \left(Y_{\text{actual}} - Y_{\text{predict}}\right)^2}{\sum (Y_{actual} - Y_{\text{mean}})^2} \tag{3}$$

$$\text{Adjusted}\, R^2 = 1 - \frac{\left(1 - R^2\right)(n-1)}{n - \text{p} - 1} \tag{4}$$

Where Y_{actual} is the actual value, Yp_{redict} is the predicted value, Y_{mean} represents the average of true values, n is the number of samples, and p is the number of predictors.

The R^2 and adjusted R^2 were 0.661 and 0.601 respectively. The result in this study show that online and offline learning activities is predictive for student performance.

From the "coefficient" and "*p* value" in Table 1, we can see that Cla.Att, Lab.SubSco, Lab.PrjSco, Online. Task, Online. Time, Online. Pageviews and Online. PR. Grade are predictors, but the coefficients of Online. Pageviews, Lab.Subjects Score were not significant, indicating that the other features are sufficient enough to predict the final grade. What interesting is that Lab.PrjSco had a positive correlation with student performance, but its coefficient was negative. There is no indication that the correlation between

Lab.PrjSco and student performance has reversed. As with single factor analysis, correlation analysis can provide point-to-point relationships so that teachers can identify positive and negative behaviors. But Students' performance might be affected differently when different behaviors are combined. A multiple linear regression model is very useful for presenting to the teacher the comprehensive effect of the combination of factors and the performance of each student.

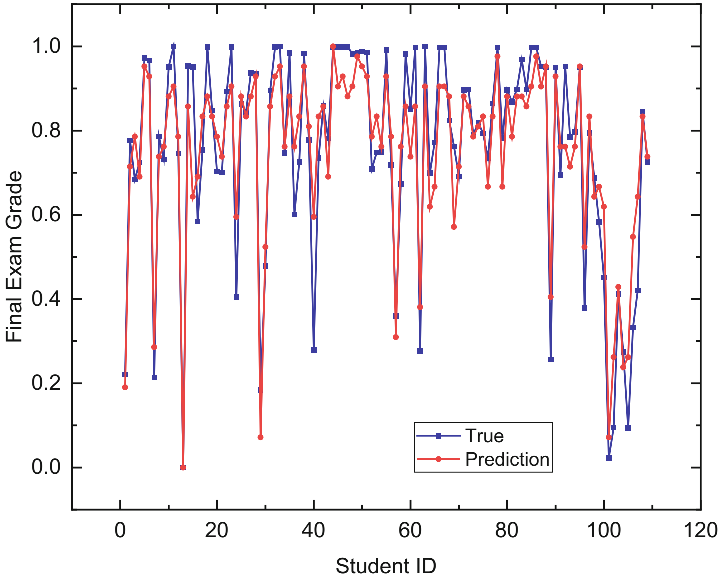

Fig. 4. The predicted results and true grade in the final exam

Figure 4 shows the predicted grade and the true grade intuitively. The horizontal axis identifies student ID, total 109 students are included. The vertical axis represents the normalized value of the final grade corresponding to ID. It can be seen that the predicted grades are generally close to the true grades. In general, the experimental results show that offline and online learning activities can predict student performance, and predictions allow teachers to gain insight into students' learning situations and discover at-risk students.

4.3 Prediction Comparison with Nonlinear Models

In order to verify the generalization of the prediction, we use most common nonlinear models including GBDT, SVR and KNN to make comparisons. R^2 is used as comparison metrics.

As the dimension of input features of the data used in this study is not high, the grid-search and cross-validation method were utilized to determine the hyperparameters of the GBDT. The start value of the number of tress (N) is set to 50, the end value of N is 400, step of N is set to10.The initial value of the learning rate of model ε is set 0.01. The start value of complexity of model C is 3, the end value is 10 and the step is 1.

The SVR model uses a Gaussian radial basis function as its kernel function, while its hyperparameters are determined through the PSO algorithm. Three import hyper parameters of SVR including the value of C that reflects the fit of SVR model for training data set, ε that represents the complexity of SVR model and γ that represents the correlation of the support vectors in the SVR are set to 3.41,0.01 and 13.21 respectively.

The number of neighbors for KNN is set to 5. All models were computed by using Python Module scikit-learn. The result is shown as Table 2.

Table 2. Evaluation index comparison of nonlinear models predictions

Models	R^2
GDBT	0.81
SVT	0.77
KNN	0.61

It can be seen that the value of R^2 of GBDT was the highest, reached 0.81 and second was SVT which reached 0.77. For KNN, R^2 was 0.61 and below to that of linear regression. The results indicate that GBDT and SVT are more robust and preferably fit the nonlinear relationship between learning activities and student performance. However, although the performance of the nonlinear models is better than that of linear regression, it's difficult for them to help teachers discover understandable explanations of how major learning activities correlated with students' academic performance due to weak interpretability. The practicability of black box models is still limited in students learning analysis.

5 Conclusion

To examine the predictability of student performance within a teaching context, this study employed one semester SPOC-based blended learning in one semester. It was found that learning data from offline and online learning activities involved in blended learning could be used to predict student performance. The attributes that influence most in our course were Class. Attendance, Online. Task, Lab.Projects Score, Online. Time and Online. Peer-review Grade. Learning performance prediction allows teachers to identify which students will perform poorly or well so that they can provide personalized, detailed intervention and guidance in advance. As SPOC-based blended learning becomes increasingly popular on campus, how to keep interpretability to increase prediction accuracy and how to find a balance between intervention time and predictive stability should be explored in a large number of experiments in the future.

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A Research on Wisdom Classroom Teaching Supported by Virtual Reality

— Take the Primary School Science "Causes and Functions of Earthquakes" as an Example

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Abstract. The rapid development of emerging technologies will profoundly change the demand for talents and teaching forms, and the future society needs more innovative and intelligent talents. Relying on artificial intelligence, Internet of Things and virtual reality, the smart classroom came into being and was widely practiced in teaching. With the development of the concept of smart classroom, how to construct smart classroom under the environment of emerging technology has become a research hotspot. This paper analyzes the supporting role of virtual reality technology in the intelligent classroom, and puts forward the application model of scientific intelligent classroom in primary schools from three stages: before, during and after class, so as to give consideration to the advantages of intelligent classroom and virtual reality technology, and provide theoretical and practical reference for promoting the reform of teaching methods.

Keywords: virtual reality · Wisdom classroom · Earthquake escape

1 Overview of Wisdom Classroom

Smart classroom is the product of educational informatization, and it is also one of the hotspots of teaching mode reform under the information technology environment. In 2015, Liu Bangqi officially put forward the definition of smart classroom for the first time According to him, the so-called "smart classroom" is an intelligent and efficient classroom based on the constructivist learning theory and made use of new generation information technologies such as big data, internet and mobile internet; Its essence is based on the analysis of big data learning and the application of mobile learning terminals. Through data-based teaching decision-making, real-time evaluation feedback, three-dimensional interactive communication and intelligent resource push, it comprehensively changes the classroom teaching content and structure, and constructs the information classroom teaching mode in the era of big data [1].

Constructing intelligent classroom is the way to realize intelligent education, and it is also the new demand of students in the current intelligent learning environment. Wisdom classroom is the environment for the development of intelligent learning. To construct

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wisdom classroom, it is necessary to apply information technology to classroom based on constructivism learning theory to promote the generation and development of students' wisdom. When constructing a smart classroom, we should pay attention to the integration of new technology and teaching, and take learning as the standard to analyze from four aspects: teaching content, students' needs, teaching tools and teaching objectives, so as to stimulate students' interest and make them learn easily and happily.

In the existing research, many scholars have constructed the application mode of smart classroom from different perspectives combined with the emerging technologies at that time. Pang Jingwen and Jie Yueguang of Northeast Normal University put forward the construction ideas and teaching ideas of smart classroom in combination with the current popular information technology in the article "Construction Methods and Case Studies of Smart Classroom in Information Technology Environment" in 2014And combined with teaching cases, they improved the teaching model, which reflected the revolutionary role of information technology in teaching. With the rise of concepts such as e-bag, flip classroom and micro-class, Pang Jingwen and others published "Construction and Case Study of Junior High School Mathematics Wisdom Classroom Based on Micro-class" in 2016. Combined with junior high school mathematics classroom, they put forward the construction ideas of new lectures, exercises and recitations under the support of micro-class, in order to promote teaching reform. During the booming period of 5G, Cai Su of Beijing Normal University put forward the idea of building a smart classroom based on 5G technology in the Practice of Multi-modal Smart Classroom in 5G Environment, which combined the advantages of 5G technology with various teaching elements to promote the complementarity between technology and teaching.

2 Overview of Virtual Reality

Virtual reality technology is a realistic visual, audio and touch integrated virtual environment, which is based on computer technology, sensor technology and simulation technology. The earliest application of virtual reality technology was Sensorama in 1956, which was a huge machine with 3D display, smell generator, stereo and vibrating seat. Several short films were put in for people to enjoy, but it was not commercially available due to its huge size. The application of virtual reality technology in education can be traced back to 1980s at the earliest, but it has not been widely concerned because the technology and media were not mature at that time.

Virtual reality technology has three characteristics: immersion, interactivity and imagination. Immersion is the core feature of virtual reality technology, which means that users will think that they are part of the virtual environment in the digital environment, resulting in the feeling of being there. Interactivity means that the experiencer can manipulate the objects in the virtual environment, and the objects in the virtual environment will respond accordingly, so as to achieve the interactive effect. Imagination means that virtual reality technology can not only simulate the real scene, but also simulate the imaginary or even nonexistent scenes in the human brain.

3 The Potential of Combining Virtual Reality with Science Wisdom Classroom in Primary Schools

In the new edition of primary school science curriculum standards in 2021, it is clearly stated that primary school science curriculum is a comprehensive curriculum with the aim of cultivating students' scientific literacy. Science has the dual nature of practicality and activity, which requires students to acquire new knowledge and improve their scientific literacy through inquiry of science.

In the practice of science teaching in primary schools, we have analyzed the following four problems in primary school science classrooms:

3.1 Exploration Process Modele

With the advancement of the new curriculum reform, teachers are required to guide students to acquire new knowledge through inquiry learning, but scientific inquiry is often fossilized into a set of fixed patterns. Many simple questions can be answered by observation. However, in order to achieve the effect of inquiry learning, teachers often complicate simple questions, which makes students lose interest in inquiry learning, resulting in more than enough curriculum questions and insufficient summarization, and it is difficult for students to acquire systematic knowledge.

3.2 Xploration Process Modele

With the improvement of information technology facilities in primary schools, teachers are keen to use multimedia in class. However, many teachers only make use of multimedia by putting the pictures and words from textbooks on electronic whiteboards. Teaching resources are PPT with a small amount of audio and video. In the teaching process, students' overall participation is not high, and there is little interaction with teachers. Multimedia courseware has a large knowledge capacity and a quick way of presenting knowledge. Many students enter the next knowledge point before they understand it, which is not conducive to the cultivation of students' scientific literacy.

3.3 Experimental Facilities Are not Perfect

Science requires a lot of experimental processes and observation contents, but many school experimental facilities have not been added after being purchased once. The loss of experimental equipment in use is inevitable, but the lack of replenishment and the backward experimental facilities make it hard to meet the needs of the classroom, which makes the experimental equipment become furnishings.

3.4 Individualized Learning Deficiency

In the new century, primary school students are exposed to more new things. Because of their different growing environments and hobbies, students need the support of personalized learning materials. Unified textbooks and lesson plans are difficult to meet the needs of different students, especially in science, an inquiry-based discipline. We should pay more attention to students' individual differences in teaching, so as to entertain students, improve students' learning efficiency and achieve good learning results.

Aiming at the above four problems, the application of virtual reality technology can improve the problems existing in the classroom.

4 The Advantages of the Combination of Virtual Reality and Classroom

4.1 ExplProvide the Implementation Conditions of Situational Teaching

Virtual reality can construct situations that no longer exist in reality, situations that are difficult to reach in another space, and situations that are difficult to simulate in reality. For example, the dinosaur era in the past, the artificial intelligence era in the future, and the desert and universe that students can't reach due to time and space constraints.

4.2 Enhance Students' Telepresence Experience

In the past teaching, it was difficult for students to empathize with the guidance of videos and pictures related to earthquake escape. However, using virtual reality technology can make students feel immersive, mobilize students' participation in various senses, stimulate students' interest, and promote students' fact-based inquiry and learning.

4.3 Realize Real-Time Interaction Between Teachers and Students

Virtual reality technology can realize the real-time interaction between teachers, students and devices. Teachers can control the interaction process between students and teaching content through pad according to the teaching needs, and with the help of real-time feedback provided by virtual environment, they can know the students' mastery and guide them.

4.4 Auxiliary Emotional Education

Primary school stage is the key period for the cultivation of emotional attitudes and values, and immersive situational learning in virtual reality environment can assist teachers in emotional education for students [2]. In the virtual environment, students will think that they are the protagonists of the environment, and they will develop corresponding emotions in the process of experience. At this time, teachers can help students form correct values with appropriate guidance.

5 Inquiry Learning Design of Intelligent Classroom Supported by Virtual Reality

"Causes and Functions of Earthquakes" is the teaching content of the first volume of the fifth grade of Science Education Edition for primary schools. Before this lesson, students have already known the structure of the earth, so this lesson focuses on the knowledge of earthquake formation in popular science and the correct measures to prevent earthquakes when they come.

5.1 Content of Virtual Reality Teaching Resources

The virtual reality resource used in this case is the immersion "earthquake escape system", which supports students to explore freely in the virtual earthquake environment. The complex escape task is decomposed into three subtasks as the key decision points, and the initial state and target state of each subtask are clear.

Situational Design. Situation design should follow the principle of authenticity and open exploration, and make use of the immersion characteristics of VR technology to present a highly simulated virtual world containing various earthquake situations. Using the interactive features of VR technology to provide students with a space to support free exploration. As shown in Fig. 1, there are three virtual situations in this resource, namely classroom, corridor and outdoor. In this environment, every control device has realistic behaviors, such as the appearance of ground light, the shaking of tables, chairs, doors and windows, the change of light and shade, etc. These effects can make students feel the danger of earthquake completely and truly, and put them into escape training (Fig. 2).

Fig. 1. Situational design

Fig. 2. Situational design

Task Design. Task design follows the principle of problem space and key decision point, and puts escape skills in meaningful decision-making tasks. Students learn by solving problems independently and reflecting on their experiences. In the classroom situation, there are two key tasks. First, when an earthquake happens, students need to hide under the table and hold the legs of the table by the handle control. Second, after the earthquake, students quickly picked up towels to cover their noses and mouths, and covered their heads with schoolbags to escape. There are two key tasks in the corridor situation. First, in the process of escape, you need to avoid puddles and power lines. Second, when students are trapped, they need to pick up iron bars and tap the guardrail for help. In the playground situation, it corresponds to a key task, that is, students need to stay away from buildings and get down or squat on the open ground (Fig. 3).

Interactive Design. The interactive design of the earthquake escape system based on VR support firstly involves the students' somatosensory interaction with VR hardware devices. VR glasses use real-time calculated virtual visual signals instead of the real world, which brings the students the sense of being in the earthquake. At the same time, students can control the spatial positioning, action synchronization and behavior driving

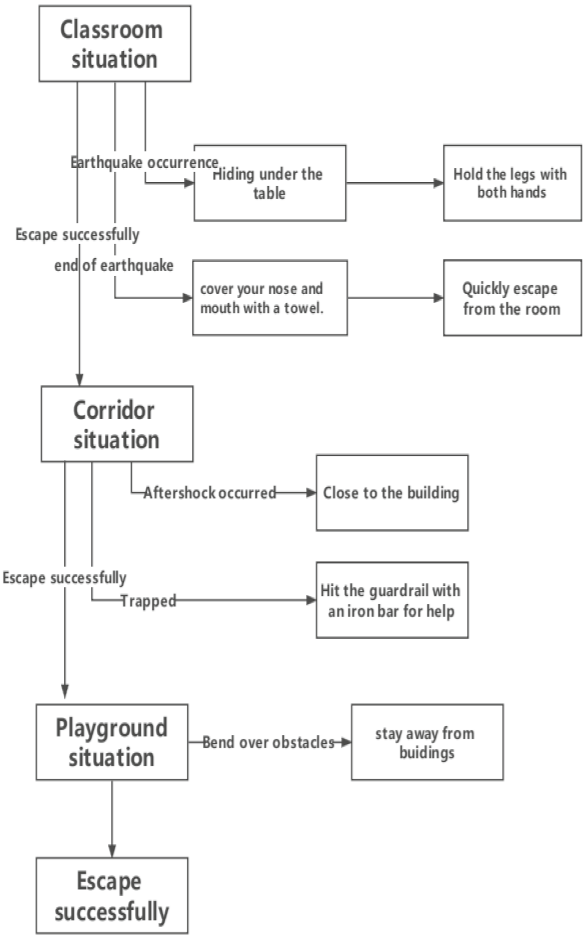

Fig. 3. Mission Design of Earthquake Escape System

of virtual characters by relying on tactile sensing system and mobile controller devices. In addition. Students can also interact with virtual elements. Students can grasp the corner of the table and pick up towels through the handle, giving students a comprehensive immersive perception experience.

5.2 Teaching Implementation Supported by Virtual Reality

After completing the initial stage of teaching resources, inquiry teaching design enters the design of teaching implementation.

Analysis of Teaching Content. The content of this lesson mainly focuses on the causes of earthquakes. Students don't know much about earthquakes, and most of them have never experienced earthquakes. Therefore, in the design, we should pay attention to linking the teaching content with students' actual life, and arouse students' interest in inquiry.

Analysis of Students' Needs. The cognitive development of fifth-grade students is in the specific operation stage, and the thinking operation must be supported by specific things. Virtual reality environment technology provides students with somatosensory interaction, which helps them better understand the teaching content. At the same time, students have already learned about the surface and structure of the earth and the crustal movement, so this lesson is not difficult for students.

Demand Analysis of Teaching Tools. This lesson mainly uses VR glasses and handles, as well as terminal equipment used by teachers and students and a whiteboard with interactive functions. The support of new equipment for intelligent classroom can enrich students' direct experience, promote students' interaction with the environment [3], and inspire students to actively explore relevant knowledge about earthquakes.

Analysis of Teaching Objectives. In the design of teaching objectives, we have formulated three-dimensional objectives according to the new curriculum standards and learners' characteristics. 1. Knowledge and skill objectives: To understand the causes of earthquakes and master the common sense of shock absorbers. 2. Process and Method Objective: Master the skills of earthquake escape through exploration in VR games, and exchange and discuss in the class. 3. Emotional attitude and value goal: to realize the power of nature; Cultivating students' interest in exploration through scientific inquiry activities.

5.3 Teaching Implementation Process

The main job of the teachers in the first part of the class is to analyze the students and the teaching content and prepare and update the teaching resources based on this. The main task of students is to preview before class and complete online self-test through the learning materials provided by teachers.

The class is mainly divided into five links, as shown in Table 1. The middle stage of the class is the core part of the wisdom class. Teachers need to carefully design and use various modal resources to enrich teaching activities and create an efficient class.

After-class stage mainly refers to teachers' tutoring for students after class. After students finish their homework, they can communicate with teachers through the communication platform and give targeted guidance to specific problems. And big data can push personalized learning materials for students and expand learning content.

5.4 Analysis of Teaching Effect

In this study, observation and interview methods are used to analyze the teaching effect, and two parallel classes in grade five of a primary school are selected for comparative analysis. Among them, Class A adopts the traditional teaching mode, while Class B

Table 1. Teaching Process Table

Teaching step	teaching process
Create a situation Raise a question	The teacher played a video of Tangshan Earthquake through multimedia, and asked the question: The damage caused by the earthquake is enormous, so how did the earthquake form?
Activating experience Propose a hypothesis	Teachers show courseware (the structure of the earth's interior) and teaching aids (hard-boiled eggs), guide students to think, and put forward different assumptions
System learning Knowledge construction	The teacher explained systematically-the earthquake was caused by the cracks caused by the collision between plates. At the same time, he asked: What measures will you take to protect yourself if you encounter an earthquake?
Cooperative inquiry Communication display	Students use VR devices to explore escape skills in a virtual environment, remember their own escape skills, and show them on the teaching cloud platform later
Process monitoring Evaluation and reflection	Teachers observe students' learning progress and completion through the teaching cloud platform and teaching big data, give personalized evaluation, and give targeted counseling to students according to the feedback results
Summarize and summarize Outward bound learning	And teachers and students systematically sort out the learned knowledge, and push personalized learning resources for students through the teaching cloud platform as after-school extended learning

combines virtual reality technology to carry out teaching activities. In practice, through observation, it is found that the students with backward grades in Class A are not active in class, showing little interest in the inquiry links in class, while most of the students with good grades can actively participate in class activities. The situation of students in Class B is different from that in Class A. Students with poor grades show great enthusiasm for learning, and their participation in class is also improved. After the end of the course, the students of the two classes were given test questions about the content of the class, and their answers were observed and their scores were counted. After observation and analysis, there is little difference in the correct rate of questions between the two classes, but for the students with backward grades, the correct rate of class B is obviously higher than that of class A. After class, through interviews with students with poor grades in two classes, it is difficult for the students in Class A to tell the skills of earthquake escape, and they don't have a deep memory of classroom activities. The students in Class B can tell the skills of earthquake escape clearly and methodically and express their deep impression on classroom activities.

This study analyzes the teaching effect from three aspects: students' interest in learning, class participation and achievement improvement. From the perspective of students' interest in learning, whether students with excellent academic performance or backward academic performance, adopting VR teaching will significantly enhance their interest;

From the perspective of classroom participation, students' classroom participation is at a high level, whether they use traditional teaching or combine VR technology to teach. However, students with poor grades have significantly improved their participation in VR class. From the aspect of achievement improvement, students with good grades in the two classes have little difference in performance in the test, while students with poor grades can obviously improve their correct answer rate by adopting VR teaching method. To sum up, the intelligent classroom supported by virtual reality has a good teaching effect, which can greatly arouse students' enthusiasm for learning and help students complete the construction and internalization of knowledge.

6 Summary

This study discusses the concepts and characteristics of virtual reality and intelligent classroom, analyzes the existing problems in science classroom in primary schools, and constructs an intelligent classroom model combining the supporting role of virtual reality in intelligent classroom. The intelligent classroom supported by virtual reality has unique advantages, which breaks the limitations of time and space and the lack of practical links in teaching, realizes the wisdom of teaching, and promotes the implementation of the new curriculum reform concept in teaching practice. It is a meaningful exploration and research.

However, virtual reality technology teaching also has its limitations, such as expensive equipment, shortage of teaching resources, shortage of teachers, etc. However, with the development and improvement of virtual reality technology, we should speed up the construction of teaching resource database, further study the combination of virtual reality technology and intelligent classroom development in practice, and constantly improve and perfect the teaching model in order to create efficient teaching and promote the generation of students' wisdom.

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Analysis and Conclusion: Children's Safety Education Games Based on VR

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Abstract. The problems of traditional safety education games, such as boring content, single scene, poor sense of experience and immersion, are gradually emerging. This paper analyzes and sums up six different kinds of safety education games, and leads to the advantages of safety education games with VR technology. This paper analyzes the application advantages and general design principles of VR technology in children's safety education games from the angles of immersion, interactivity and situational style, summarize the future trend of children's safety education games based on VR technology.

Keywords: Safety Education Games · Design Principle · VR Technology · Application Advantages

1 Research Background

Children's safety has always been the focus of attention from all walks of life. The physical and psychological development of kindergartens and primary school students is not yet mature, and they have a strong curiosity about new things and unfamiliar environments, and their awareness of self-defense and safety is weak. Traditional child safety education is generally carried out in the form of brochures, class meetings, etc., which is not timely and continuous, and has a weak sense of real experience. In addition, the level of related hardware industry chain has been greatly improved, and the emergence of network architecture and VR platform software has accelerated the application of "VR+ game", and the market demand has been increasing [5]. Therefore, the development of children's safety games based on VR technology has become a top priority, and gradually entered the field of practical teaching, which is expected to change the current situation of children's safety education and teaching.

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2 Analysis of the Content of Children's Safety Education

2.1 Children's Safety Education Measures at Home and Abroad

The strategies used in children's safety education abroad are different from those in China. For example, France allows the armed forces to enter the campus and provides separate mobile teams in school districts to prevent violent incidents; During the peak hours of school, arrange auxiliary police to keep order, ensure that students are handed over to parents, and avoid safety accidents. Japan has established a security system integrating schools, parents, communities, hospitals and other departments, and installed cameras on campus, the classroom is equipped with safety and explosion-proof devices, and the school regularly organizes earthquake escape drills to enable students to master the necessary escape skills through practice. Domestic safety education absorbs foreign good practices and effectively combines with domestic mechanisms. For example, auxiliary police are equipped at the entrance of primary schools in China to direct pupils to cross the road, and teachers on duty are responsible for handing over students to their parents, the campus is also equipped with high-definition cameras, and safety education activities such as escape drills are regularly organized.

2.2 Analysis of Traditional Safety Education Games

Children's safety education refers to the prevention, control, elimination or avoidance of accidents or catastrophic accidents that cause personal injury, an education to safeguard children's life safety includes four aspects: school education, family education, social education and educational mechanism [7]. As a practical educational theme, the game implementation process is uneven. Traditional children's safety education activities mostly stay in the theoretical knowledge of games to teach children, it doesn't really make children feel the interactivity of the game.

Safety Education Game 1: Fire Safety. Fire drill was created by Beijing Shikongmen Technology Co., Ltd., as shown in Fig. 1. This system makes use of virtual reality technology to create a three-dimensional simulated campus environment, and simulate what emergency and escape measures should be taken in case of initial fire and uncontrollable fire. Compared with the general simulated fire emergency and escape, it has the advantages of high authenticity, task, fun, strong interactivity and lower experience cost, it is not affected by the physical area, is not limited by the location, and can experience learning anytime, anywhere. This game has four main features. (1) Strong interactivity: Users can switch and move their perspectives through VR helmets, and can interact with virtual scene objects. For example, take a towel to cover your nose and mouth, bend forward, take a fire extinguisher, etc., immersion learning fire safety knowledge content; (2) Smooth experience: the system contains a lot of UI and voice, used to prompt the experiencer's operation. Make the operation more smooth and convenient; (3) Walking: the experiencer can walk in the virtual environment by controlling the handle; (4) timeliness: in the actual fire environment, no matter the initial fire or the uncontrollable fire, it is safest to try to extinguish the fire source or escape from the fire in the shortest time. The timeliness of real fire simulated in this system. The experiencer is required to put out the initial fire within a certain time and escape from the fire within a certain time, otherwise, fire fighting or escape will fail.

Fig. 1. Game interface of Fire Drill.

Safety Education Game 2: Earthquake Escape. Earthquake Simulator VR is a virtual earthquake simulator made by HTC Vive, which was released on STEAM platform in June 2017, as shown in Fig. 2. Using virtual reality technology to make a three-dimensional simulation of home earthquake environment, experience a short earthquake and fire simulation, and learn practical survival skills. In an interesting and immersive environment, it is suitable for family study. This game has four highlights. (1) scientific research and development with rigorous content; (2) Scene restoration, immersion teaching, and true restoration of the earthquake disaster scene; (3) Based on physical simulation. According to the real data, create a virtual information environment in the multidimensional information space, which has the feeling of being there, the ability of perfect interaction with the environment, and helps to inspire ideas. Learn earthquake-related knowledge by entertaining and playing games.

Safety Education Game 3: Drowning Prevention. VR Drowning Prevention Course was developed by Guangzhou Yichuancheng Information Technology Co., Ltd., as shown in Fig. 3. It is a high-tech enterprise integrating virtual reality content production, technical service and product research and development. In the VR drowning prevention system experience, the team used 3D animation technology, 3D modeling and special effects technology to simulate the drowning

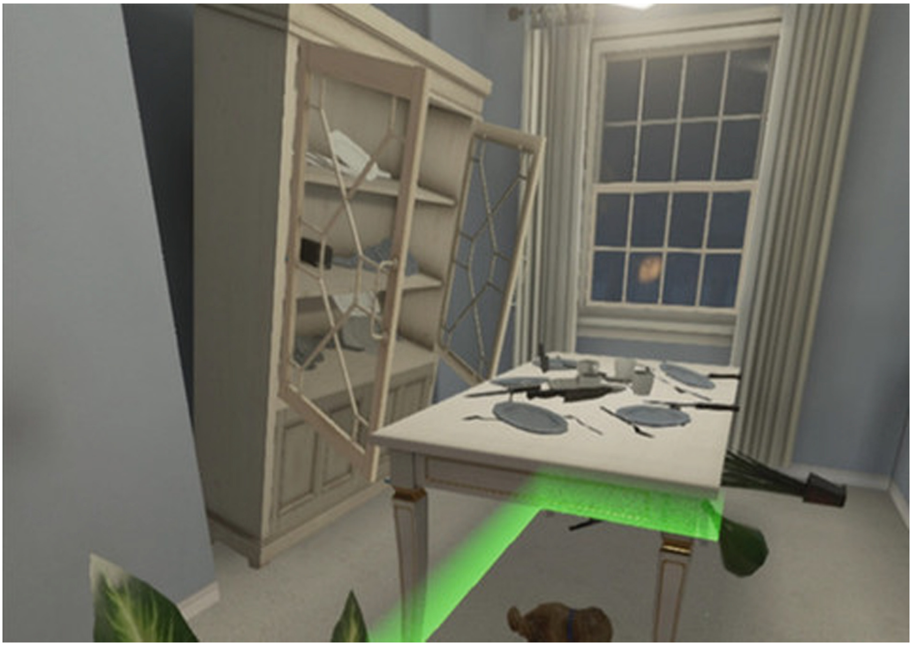

Fig. 2. Game interface of Earthquake Simulator VR.

picture from the first person perspective in the simulation plot, let children simulate how to rescue themselves after drowning in common drowning areas. The game pays great attention to the theory of drowning prevention, and users can choose the rescue area by themselves, which can lead to multiple ending scenes.

Safety Education Game 4: Traffic Safety. VR Drunk Driving was developed by Anhui Peijing Exhibition Design Engineering Co., Ltd., as shown in Fig. 4. In order to further strengthen the publicity and education of safe driving traffic, strengthen the awareness of driving safety, legal system and civilization, peijing Technology launched VR drunk driving simulation experience system, a 360 full immersion drunk driving simulation experience. The VR Drunk Driving game combines VR technology with dynamic technology and 3D modeling technology, and the experience passes the VR helmet, experience a complete three-dimensional panoramic picture. During the drunk driving experience, you can guide the operation through the dynamic interaction of voice, text and guidance. The experiencer feels as if he is driving, and simulate the environmental effects such as blurred vision and vertigo in the process of reality, without any "sense of disobedience". The advantages of this game are highly restored accident scene, immersive experience, high learning and education efficiency, simplicity and safety, and breaking various restrictions. It is more intuitive to integrate the game from the hero's perspective. This is also a major trend in the domestic

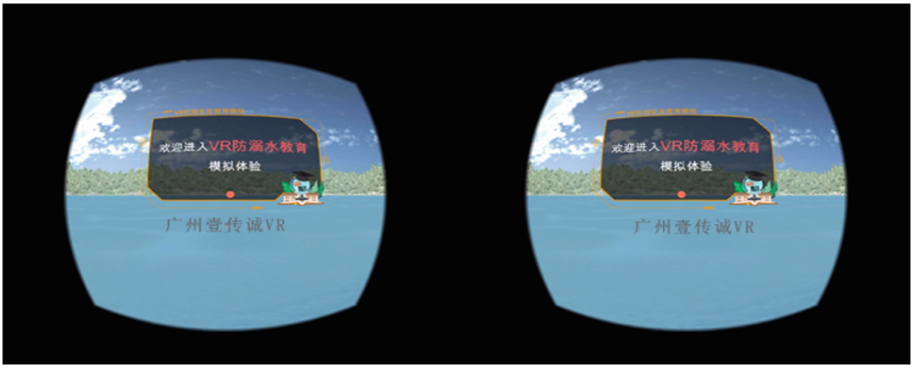

Fig. 3. Game interface of VR Drowning Prevention Course.

security education game market at present, taking advantage of the particularity of its users, children are more willing to immerse themselves in the game plot as the protagonist.

Fig. 4. Game interface of VR Drunk Driving.

Safety Education Game 5: Anti-abduction. VR Anti-abduction and Anti-fraud Education is a safety education game, which was also developed by Guangzhou Yichuancheng Information Technology Co., Ltd., as shown in Fig. 5. Using 3D modeling and VR panoramic technology, the 720 panoramic view shows the common abduction and deception scenes, and the experiencer decides the story direction through choice, experience all kinds of dangerous situations being tricked, how to escape safely when encountering dangerous situations, and learn the knowledge of preventing abduction more intuitively and vividly. Children are attracted to the storyline by means of entertainment games. With its rich storyline and vivid game pictures, attracted many players to join, and made up for the traditional form of safety education based on books on the market.

Fig. 5. Game interface of VR Anti-abduction and Anti-fraud Education.

Safety Education Game 6: Preventing School Violence. The game bully is a campus masterpiece developed by the American school system, as shown in Fig. 6. For the hero Jimmy Hopkins, a 15-year-old troubled youth, after failing in many schools, he arrived at another place wherehe settled, and it was also the place where the climax of his life took place —-Bullworth Academy. On the surface, the school is calm, but behind the scenes, there are serious problems and mixed fish and dragons. Bully comes from classic PC transplant works, and is a popular game on multiple platforms; compact plot, created by the latest Unity technology. This game has injected great efforts into the development team, both in considering the publishing platform and designing the storyline. At the same time, it also provides a blueprint for domestic games. Domestic educationalgames still need to learn from foreign excellent game works in terms of immersion and storyline, and in addition, they should be built with local mechanisms.

After analyzing the above kinds of games, it is not difficult to see that the traditional two-dimensional animation games are difficult to achieve the immersive effect. With the blessing of virtual reality technology, the field of educational games has achieved a qualitative leap. In the previous analysis of these games, it is found that both domestic and foreign educational games pay more attention to immersion, which is also a major advantage of VR technology. In addition, it can

Fig. 6. Game interface of Bully.

be re-entered, effectively reducing the cost, making this technology widely used in education, thus launching a new concept of "education +VR". For example, the hot topic now is Metauniverse, internet plus and other modes. Traditional educational games lack situational learning, embodied cognition, flow theory, win-win cooperation and other factors, which are also the main factors impacted by emerging technologies. Therefore, this paper is committed to changing the traditional propaganda mode of safety education knowledge, and discusses the adoption of open interactive narrative structure-multi-ending choice based on VR technology, the macroscopic conception of setting up reasonable storylines and scenes and eliminating the single and low efficiency of traditional linear narrative games. Make children explore the game situation independently, decide the ending according to their preferences, rather than a single ending, and increase their personal sense of accomplishment, so as to achieve the goal of safety education.

3 Advantages of VR-BASED Children's Safety Education Games

Virtual Reality Technology is abbreviated as VR technology, which simulates a three-dimensional virtual environment through computer simulation and other technologies, users can immerse themselves in the virtual environment through special mobile devices and interact with virtual characters in real time, interaction, imagination, immersion and intelligence are its four basic characteristics [4]. VR-based interactive means provide players with new ways to play in the field of educational game applications. By carrying independent exploration space for children, add entertainment elements to promote children's sense of participation, and reduce children's psychological fear in the face of fire and drowning. Generally speaking, VR technology has six advantages compared with the traditional propaganda methods of safety education.

3.1 Learning Situation

Situated Learning focuses on the essential role of students' real situations in the learning process, and emphasizes the interaction and practice between students and the environment [1]. VR technology provides an immersive learning environment for children. Using mobile devices, children can intuitively experience the superposition of "real environment", and children can choose scenes in real time to enter the next safety education section. It can help children construct real game situations and make them have "sense of presence", which can enhance children's interest in learning and reduce possible risks. For example, in the Fire Drill game, users can switch and move the viewing angle by carrying the HTC VIVE helmet, and can interact with the virtual scene. Check the hidden fire safety points in living rooms, bedrooms, kitchens, bathrooms, balconies and other places one by one, and learn the fire safety content by immersion. Compared with traditional safety education games, it has a high degree of reduction, which is also the advantage of paying attention to situational learning.

3.2 Embodied Cognition

Embodied Cognition theory means that knowledge construction can be carried out from external perception through body movement [2], this theory puts forward that cognition is situational, and the environment is also a part of the cognitive system, so the external environment can reduce the cognitive load [6]. In the virtual reality environment, VR technology fuses the information of children and virtual objects in the real environment, and controls the walking of virtual characters through limb movements, in the interactive feedback scene, the accident scene in the real environment can be simulated instantly, so that the self in the game can avoid the safety accident, and then the children's participation and immersion can be improved. Among them, the earthquake sensing in Earthquake Simulator VR captures this feature. When an earthquake occurs, the head-mounted display device will appear the illusion of fainting, as if it were at the earthquake site. The feeling of drowning and suffocation in the game of VR Drowning Prevention Course also uses human visual characteristics to reduce cognitive load through external environment.

3.3 Reduce Costs and Avoid Safety Accidents

More and more games begin to pay attention to multi-ending directions and meet individual choices. In this respect, there can be many endings of the game settings of bully, and the choice in the middle is relatively personalized. Along the main line of the game, the virtual characters are also rich, with ups and downs, and they don't stick to a road to victory. While the other five games generally have only one or two endings. For example, the game VR Anti-abduction and Anti-fraud Education can choose to go with strangers or not. If you go, abduction will happen until you come back; the other is to choose not to go with strangers, to pass the game smoothly, and the plot is relatively simple, which is also the overwhelming phenomenon in the current safety education game market. In designing games, the interactive narrative structure-multi-ending choice model can be appropriately added. Children can choose their own scenes and ways. Different scenes have their own story lines and endings, and every child can DIY their own safety education route.

3.4 Combining Traditional Learning with VR Technology

The technical advantage of VR is that it can experience safety education activities many times without extra cost, which can make up for the high cost of field training or study. Configure a variety of scenes and story lines and corresponding endings according to the differences of personal interests, purposes and ways. Operating in a relatively safe environment ensures the life safety of children and staff, and children experience activities that are difficult to contact or extremely dangerous in real life without bearing the real consequences. Such as earthquake, fire, traffic safety, etc. In the game of Earthquake Simulator VR, we can experience the earthquake scene in different scenes many times. In reality, it is difficult for children to experience real earthquake scenes many times. In the game of VR Drunk Driving, users can drive on the road independently, experience the danger of drunk driving and learn the road traffic safety law, which also reduces the losses in reality considerably, and can experience many drunk driving "journeys" without purchasing the game twice.

3.5 The Picture Is Realistic and the Learning Goal Is Clear

Through VR technology, build a virtual new learning scene, and make use of the convenience of mobile devices and the real-time nature of interactive feedback to produce different story lines and endings. Timely voice broadcast and option prompt sound display, carry out children's safety education, and combine traditional learning with VR technology. In games such as VR Drowning Prevention Course and VR Anti-abduction and Anti-fraud Education, besides paying attention to the exquisite interface of the game, there will be knowledge explanation after the user makes a choice. In order to achieve the goal of safety education, it reflects that educational games are the combination of education and games, and they are impartial.

3.6 The Picture Is Realistic and the Learning Goal Is Clear

During the game, VR technology can establish a three-dimensional animation perspective with realistic scenes, so that children can be immersed in it. Children receive safety education knowledge in the process of experiencing games, master safety self-help skills in a relaxed and entertaining environment, and enhance safety awareness in a strong immersion environment. The pictures in these six games are relatively realistic, and they fit in with real life. It also reflects that in the future educational game market, being close to real life is the pursuit and purpose of most games, which is also to make users feel friendly and more immersed in games.

4 Design Principles of Children's Safety Education Games Based on VR

It has become a trend for education to use network technology or intelligent tools as interactive media to complete learning content. This paper analyzes the design factors of children's safety education games under virtual reality technology from three aspects: human-computer interaction, content structure and educational significance.

4.1 Human-Computer Interaction Level

Human-Computer Interaction and Real-Time Feedback. When interacting with the children's interface, it has its own mechanism of free operation and timely feedback of options, free selection and switching of scenes, and free feedback of option results, update the feedback judgment result in real time, and guide children to enter the next safety education situation and content. Fire drill, Earthquake Simulator VR, VR Anti-abduction and Anti-fraud Education are relatively good in human-computer interaction and real-time feedback module. Users can freely choose the plot and the tools they use, and mobile devices can give feedback in real time to achieve the real-time human-computer interaction effect.

Immersion. Children can experience realistic situations in games, enjoy the dynamic music effect, get the story, and encourage children to explore the next safety education scene, so as to get the corresponding score. The plot and scene of the story are very close to real life, and children can immerse themselves in it to find their own ending. All six games focus on immersive experience, which is one of the biggest highlights of VR games.

Fun. Traditional safety education games are not very prominent in terms of fun and entertainment, and many entertainment factors are added to virtual games. For example, experience different scenes of play greatly satisfy that children's competitiveness and sense of accomplishment of this age group, while playing games, it also builds the ability of independent thinking and inquiry, and achieves the ultimate goal of safety education, which can be described as killing multiple birds with one stone. Among them, Earthquake Simulator VR has three scene modes: school, home and outdoor, showing the situation of earthquake disaster in all directions.

4.2 Content Structure

Storyline. Children should be the core of the storyline, and attention should be paid to the reduction or blurring of violent and bloody images when writing the storyline. Set rich story lines and plots to enhance children's participation and immersion in games; during the game, pay attention to the connection between the upper and lower scenes, and the following plot should be generated by the feedback from the previous scene, with meticulous logic and continuity. There are many bloody and violent scenes in bully games, which are also caused by different game mechanisms and ideas in foreign countries, while domestic games pay more attention to this aspect. For example, there won't be too bloody scenes in the collision plot of VR Drunk Driving.

Audio-visual. Beautifully designed game characters that conform to children's aesthetics, realistic game pictures with dynamic sound effects and action prompts, intelligent voice broadcast and option setting are adopted, and the text content should be matched with appropriate pinyin, which presents a warm and novel game space for learners. Looking at these six different types of games, it can be seen that voice broadcast, background music and game screen are more in line with the scene, which is also the key based on VR technology.

Rule. When entering the game, you first need to choose a situation; secondly, it is impossible to enter the back scene before the last scene is completed. On the one hand, children can develop a good habit of finishing well; on the other hand, it has a gradual effect. And the establishment of the back scene is completed through the interactive feedback between children and the previous scene. Finally, when designing the rules of the game, we should understand the rules from the children's starting point, so that the rules will not stifle children's innovative ability and imagination.

4.3 Educational Significance

Purpose. Children can master safety education knowledge and skills such as self-help and escape after experiencing a series of safety story feedback, effectively prevent safety accidents in real life and enhance children's awareness of self-protection. Extensibility. Through the combination of children's safety education games and virtual reality technology, it also provides new ideas for the popularization of other disciplines or safety education knowledge, and broaden the road for future VR safety education games.

5 Summary

Game is one of the most closely integrated fields with VR industry, and now 3D games cover almost all technologies in VR field [3]. VR technology not only constructs virtual learning situations for learners, comprehends learning content from many aspects, combines educational game elements with intelligent technology, and enhances the fun of the tour, but also provides a new power source for the popularization and development of children's safety educational games. This paper analyzes the advantages and disadvantages of six traditional safety education, and summarizes the advantages and design principles of VR-based children's safety education games. The purpose is to provide ideas for the domestic children's safety education game market in the future, so that it can not only be used as a display, observation and experience tool, but can really help children to have a deeper understanding and construction.

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A Four-Step Teaching Pedagogy of Gradient, Divergence and Curl in Electromagnetic Field and Waves Course

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Abstract. As vector functions of space and time, electromagnetic field is conceptually abstract and hard to visualize which brings obstacles to students' understanding. Vector analysis, including not only the vector algebra but also the gradient, divergence and curl operation, maybe the first level barrier and also foundations of following learn of electromagnetic field and electromagnetic waves. In this paper, a four-step teaching pedagogy containing analogy, traditional lecture, visual graphic display and manual programming experiment was proposed and MATLAB software was applied in the visualization teaching of gradient, divergence and curl with its excellent programming and simulation ability. Demonstration of simulations in classroom teaching and manual programming in experimental teaching were both implemented to enhance student comprehension and learning of vector operations, overcome major hurdles raised by a lack of mathematics knowledge, and benefits for the electromagnetic fields and waves course would be reflected gradually.

Keywords: analogy · visualization · vector analysis · electromagnetic · MATLAB programming · experiment

1 Introduction

Electromagnetic field and waves theory course (EMT) is a compulsory course for major such as communication engineering and electronic information engineering. Since the learning object-field and wave-is extremely abstract and mathematically rigorous and there are a large number of mathematical theory operations throughout the EMT course, students find it difficult to grasp, which is popular phenomenon in almost all schools or departments distributed in different regions. Traditional methods like blackboard & Chalk and PowerPoint teaching will not attract students' attention continually while taking a heavy workload to teachers, unsatisfactory effect and scores to students, teachers find it difficult to lecture.

Except the classroom environment, seating arrangements and collaboration pattern may influence the effect of teaching [1], teaching methods, teaching tools and learning styles were developed in order to offset gaps between the teaching and learning. The

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negative and positive aspects of teaching methods such as Blackboard & Chalk, PowerPoint, Smart Board and Overhead Projector under lecturers view and students view were compared, discussed and Project-Based Learning was proposed as the more feasible learning style than Problem-Based Learning for university engineering programs [2]. Analogy method was applied EMT course and the analogy objects covered General Physics course, Circuit Analysis course, Physical Quantities Establishment Processes [3].

Visual method is becoming focus way enhancing the teaching effectiveness. FEA and mathematic software like ANSYS, MATLAB, Mathematica is widely applied during the course. Virtual models including Electromagnetic wave polarization, Surface waves, etc. developed using Ansys HFSS were used to increases students' interest in learning [4]. Remote visual experiment of the rotating magnetic field was carried out with finite element model of three-axis hall sensor [5].

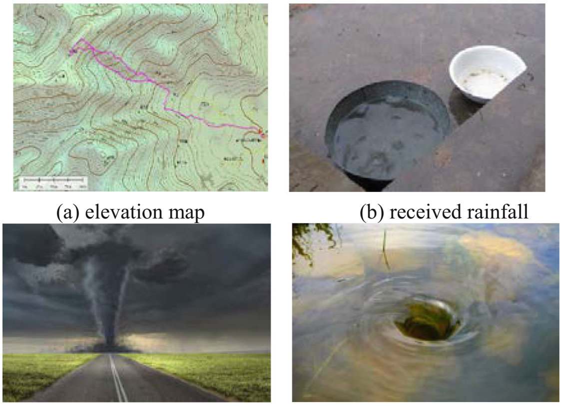
Mathematica software was applied not only in the electric and magnetostatic field [6, 7] but also the flow in porous media similarity theory teaching to accelerate understanding the subjects [8]. MATLAB software, with its properties containing easy to use, special toolboxes and graphical interface, abundant tools for design, implementation, verification, and validation, is relied by thousands of engineers and scientists around the world for modeling and simulating complex systems; and will serve as an advantage to the students throughout their professional careers. One-dimensional Maxwell's equations in differential form solving with numerical modelling [9], virtual electromagnetic laboratory contains several electric, magnetic and current experimentations [10] was realized using the software. The MATLAB GUI enables users (students) to make a set the difficult brushless direct current design more visual and comprehensible for students through step-by-step procedure [11] while programming assignments were designed to deepen student engagement and accommodate different learning styles so students can learn more effectively [12]. Many knowledge points of EMT course were also made into visualization courseware from the electric field [13], the magnetic field [14] to the time-varying electromagnetic field [15] and the electromagnetic wave [16].

However, vector analysis, as the first part and mathematical fundamentals of EMT course, whose visualization had few mentioned by scholars. Indeed, students would refer the vector algebra operation such as addition, subtraction and multiplication during the past mathematics courses, but very few students may contact conception of gradient, divergence and curl, whose abstractness causing difficulty to the learning. Four-step teaching method containing analogy with natural phenomena, traditional lecture, visual graphic display and manual programming experiment is proposed to enhance student comprehension and learning throughout the EMT course.

2 Four-Step Teaching Method in Vector Analysis

2.1 Analogy Teaching Step

In the first analogy step, natural phenomena or objects having similar features with gradient, divergence and curl will be leaded-in before the central lecture/PPT teaching. For the above three teaching knowledge, elevation map with sparse unequal contour, received rainfall using barrels of different shapes, tornadoes of different intensities and directions is introduced as analogies as shown in Fig. 1 whose properties and relationship with gradient, divergence and curl will be described.



(a) elevation map (b) received rainfall (c) tornado (d) water vortex

Fig. 1. Natural phenomena chosen as the analogy objects

For the gradient teaching, a hill with elevation map is used to image the related concepts. Contour line is signed as the scalar field, change rate of direction person climbing from the bottom to the top is signed as the directional derivative, then the most precipitous direction change rate will be signed as the gradient.

For the divergence teaching, received rainfall is used to image the flux whose amount will change due to the turn of barrel indicating varying flux. Specially, if the barrel has no bottom and there will be no rainfall remained, thus will be signed as the flux is zero. Then, based on the differentiation, the area of the barrel is reduced and finally becomes an individual unit and flux throughout the individual unit will be signed as the divergence.

For the curl teaching, tornadoes or water vortex is used to image the circulation quantity and vortex source. For different points in the tornadoes or water vortex, there will be varying attractive force signed as the varying circulation quantity directions is introduced as analogies as shown in Fig. 1 whose properties and relationship with gradient, divergence and curl will be described.

2.2 Lecture/PPT Teaching Step

Lecture/PPT teaching step follows analogy of actual, visual natural phenomena. As the traditional teaching mediums, definition and calculation equation, properties of gradient, divergence and curl with related concepts as directional derivative, flux, circulation will be expounded using blackboard & Chalk and PowerPoint.

Taking directional derivative and gradient as an example, change rate in one certain direction is defined as the directional derivative and there will be much directional derivative like person may climb the hill in arbitrary path. For a scalar field Φ and one point P in the field, directional derivative of P with one direction ***l*** is calculated by Eq. (1):

$$\frac{\partial \varnothing}{\partial \mathbf{l}} = \frac{\partial \varnothing}{\partial x}\frac{\partial x}{\partial l} + \frac{\partial \varnothing}{\partial y}\frac{\partial y}{\partial l} + \frac{\partial \varnothing}{\partial z}\frac{\partial z}{\partial l} \tag{1}$$

When there is the maximal directional derivative, the value and direction is defined as the gradient, whose value is calculated by Eq. (2):

$$grad\varnothing = \frac{\partial \varnothing}{\partial x}a_x + \frac{\partial \varnothing}{\partial y}a_y + \frac{\partial \varnothing}{\partial z}a_z \tag{2}$$

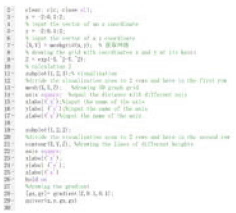
and the physical meaning is the steepest route selected from a certain point P represents direction and the travel speed in the route represents the numerical size of the gradient.

2.3 Visual Teaching Step

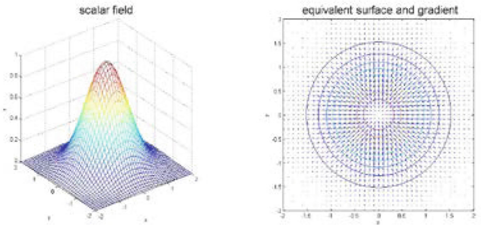
Visual graphic display step is the third step and teachers will demonstrate several examples of gradient, divergence and curl. Since the example may use cylindrical coordinate system or spherical coordinate system, conversion to rectangular coordinate system has become the primary work followed by code editing according to the equation of the example.

Taking gradient as an example, program code may be explained and calculated results of scalar field and gradient generated by codes will be visualized and projected on the large screen. Programming code mainly consists of three parts: the interval definition and grid drawing; the calculation of the equivalent surface and gradient; the result visualization using MATLAB tools. Figure 2(a) shows the software code and Fig. 2(b) shows the visualization graph of scalar field, equivalent surface and gradient with Eq. (3).

$$Z = e^{-\rho^2} \tag{3}$$



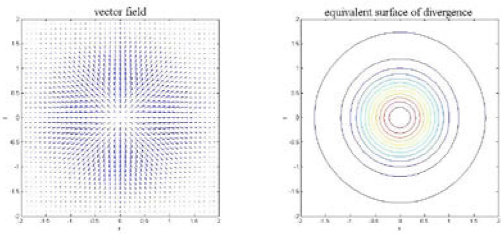
(a) MATLAB programming code



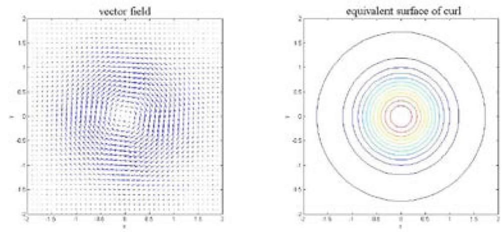
(b) visualization graph

Fig. 2. MATLAB code and visualization graph of gradient related concepts

Similarly, vector field, divergence and curl may also be calculated and visualized. Figure 3(a) shows the visualization graph of vector field, equivalent surface of divergence while Fig. 3(b) shows the visualization graph of another vector field, equivalent surface of curl.



(a) visualization graph of vector field and divergence



(b) visualization graph of vector field and curl

Fig. 3. Visualization graphs of divergence and curl related concepts

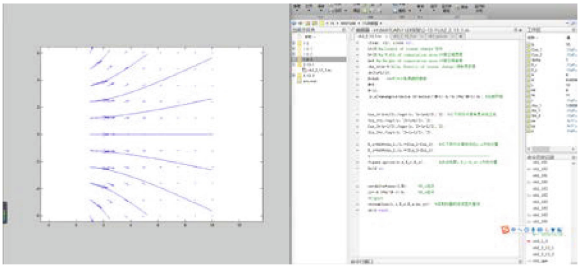
2.4 Manual Experiment Step

Syllabus of the EMT course was changed last year and 8 experiment classes were added for the course. Teaching group designed three experiments using MATLAB software simulating knowledges as vector analysis, distribution of electric field and propagation of the uniform plane wave (UPW) during the course.

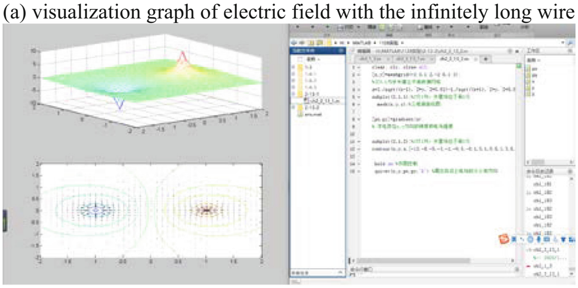
More than half of the students could finish the experiments and get the corresponding graphs of the under their own programming, some students needed extra guide for the experimental process and few students had to review how to do the transform between different coordinate system. Visualization result of the last two experiments: distribution of electric field and propagation of the uniform plane wave (UPW) finished by one student was proposed in Fig. 4.

3 Efficacy Assessment and Analysis

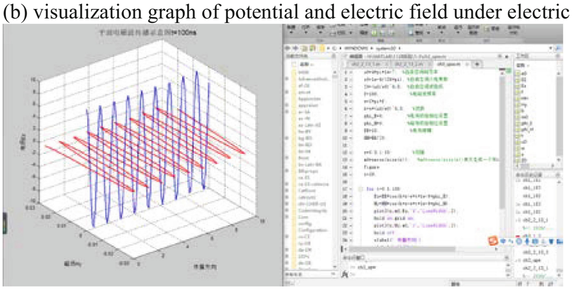
A questionnaire with 8 questions was dispensed to each student used as the assess tool. 40 students were asked to fill the questionnaire with the five-level Likert scale, where “1” means strongly disagree, “2” means disagree, “3” means neither agree or disagree, “4” means agree, and “5” means strongly agree. The corresponding students’ responses obtained through evaluation sheets are summarized in Table 1. Additionally, the same Table shows the average of each question.



(a) visualization graph of electric field with the infinitely long wire



(b) visualization graph of potential and electric field under electric dipole



(c) visualization graph of the propagation of UPW

Fig. 4. Visualization results on two experiments finished by one student

As it can be seen, the average grade of each question is equal or higher than 4.00 in the 1.00–5.00 scale. This feedback indicates quite positive learning experience and great interest by students. According to the results about analogy (Questions 1–3), elevation map, received rainfall, tornado and water vortex, chosen as the analogy objects were accredited by about 90% students. Tornado and water vortex gained least approval. In my opinion, one reason maybe they can simulate vortex and direction of curl from the surface phenomenon, but it is hard to elaborate circular rector, circulation area density and curl from the deep mathematical meaning and physical properties.

The next item focused on the programming and visual display (Questions 4–6). Nearly all students found visualization beneficial for their understanding while several students reported difficulties in the code editing. Part of the reason maybe they did not lay a solid foundation in the former MATLAB software learning causing trouble. Meanwhile, transfer among different coordination systems maybe problems that someone would not finish the code editing tasks from question 5.

Table 1. Questionnaire and the corresponding results

Questions	Levels					
	1	2	3	4	5	Average
Consistency of elevation map as scalar field and gradient analogy object selection	0	0	2	26	12	4.25
Consistency of rainfall as flus and divergence analogy object selection	0	0	2	25	13	4.275
Consistency of tornado and water vortex as curl analogy object selection	0	1	4	25	0	4.1
The MATLAB programming is benefit for the review of the three coordination systems	0	2	5	24	9	4
The visualization graphs make the abstract concepts easy to understand	0	1	1	22	6	4.325
The MATLAB programming is easy to learn	1	3	2	19	5	4.1
Analogy and visualization generated intuitive impression for the vector analysis	0	1	2	15	22	4.45
The four-step pedagogy enhance my understanding of vector analysis	0	1	3	16	20	4.375

For the function as four-step pedagogy to the learning of vector analysis, there was positive feedback from the Questions 7 and 8. More than half students gave “5” means strongly agree during the questionnaire.

4 Conclusion

This paper presents a four-step pedagogy for the vector analysis teaching in which analogy and visualization method were supplemented to traditional lecture/PPT teaching method, making students understanding vector analysis easier than simple, single explaining. The last manual experiment step could enable students to observe the visual results and review knowledge, improve their practical ability.

The four-step teaching pedagogy consisted by analogy, lecture, visual display and experiment is convenient to applied to other aspects of the EMT course and would be an effective pedagogy with our practice. The analogy and visualization instruction improves the teaching and learning process of vector analysis by comparing similar natural phenomena and gradient, divergence and curl simulation models. It also transforms abstract and complex mathematical equations into the visual representation, which improves the understanding of the students and helping the student to comprehend some difficult concepts like vector field and equivalent surface.

However, teachers should be excellent or proficient in the course and deeply analyze the teaching knowledge points. Aimed at sophisticated teaching effect, it is necessary to deeply analyze the knowledge points and some issues that need to be paid attention to when using analogy teaching method. Macro planning before the course starts should be taken to determine where and when to use the analogy in order to achieve effective analogies, then typical and suitable objects or phenomena needed to be chosen in order to use the analogy step well.

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Research on the Virtual Teaching of History Subject in the Process of Meta-universe

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Abstract. Meta-universe is a kind of Internet form that integrates many new technologies, and it has great development potential in the education industry. This paper points out the present situation of the application of Metauniverse in education and the problems in history teaching, and discusses how to carry out virtual learning of history course in Metauniverse. Virtual reality technology can overcome the problem of abstract knowledge in history teaching by creating virtual scenes, combining visual, auditory, tactile and other sensory systems, and increase learners' immersive feeling, thus improving learners' learning effect.

Keywords: meta-universe · history teaching · virtual reality technology · the virtual scene

1 Research Background

With the development of virtual reality technology (VR) and the emergence of meta-universe concept, more and more people apply it in military training, medical research, scientific education and other fields. Virtual reality technology (VR) has three characteristics: immersion, interactivity and imagination. Immersion means that users completely put themselves in a virtual scene and feel the same way through tools. Interactivity means that the created virtual scene can interact with users and show the behaviors that the real world can achieve. Imagination means that the virtual scene can join the imagination of the producer in addition to the real scene to create objects other than the real scene, which makes the scene more vivid.

Meta-universe is a new form of Internet, which is the combination of virtual and real, which is produced by integrating various technologies. Users interact with other users in the virtual world through audio-visual perception, which makes users feel present. Metauniverse is a 3D virtual world that connects all people with each other. People have their own digital identities in Metauniverse, and they can interact with each other and create anything they want in this world. [1] The application of meta-universe will bring about great changes in various fields, and the realization of educational meta-universe will also have a great impact on subject teaching. Educational meta-universe can endow educators and learners with virtual digital identities, open up virtual teaching places, and make both sides of education interact in virtual teaching places.

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At present, there are various problems in history teaching, such as too single knowledge, boring teaching process, etc., coupled with the long history time, which can't make students resonate with the contents of textbooks, resulting in students who are interested in history generally being tired of learning and other emotions, and the teaching goal is difficult to achieve. Only when students are interested in history, can history teaching have a good learning effect. Making use of the advantages of Metauniverse to complement each other's weaknesses in history teaching and designing the abstract problems in teaching content with virtual reality can not only enhance the interest of history learning, but also stimulate students' learning motivation.

2 The Development Status of Education Universe at Home and Abroad

The concept of meta-universe was first put forward in Avalanche, which describes meta-universe as a virtual city parallel to the real world. In October, 2021, Zuckerberg renamed Facebook Meta, and the concept of Metauniverse officially entered the public's field of vision, becoming one of the most popular words in 2021.The year 2021 is also called "the first year of the Metauniverse". Thanks to the development of virtual reality technology (VR), the research on its application in education and teaching is increasing year by year, but the research on educational meta-universe at home and abroad is still in its infancy. Invact Metaversity is committed to making the learning platform the intersection of education and meta-universe, and is committed to combining virtual reality technology with education. NYU campuses founded by new york University all have corresponding names to show the names and functions of teaching buildings. Besides, new york University also held Metauniverse Art Exhibition. In May 2020, the University of California, Berkeley held a virtual graduation ceremony in the Metauniverse. In October, 2021, Tsinghua University launched the Metauniverse Special Plan and the Metauniverse Project of Arts and Sciences, presenting the achievements of future science and technology museums, museums, space exploration and other projects.

Searching on CNKI with the keyword "virtual reality technology + education", according to the results, virtual reality technology (VR) is more widely used in medical education, science education, chemistry education, geography education, but its application research in history education is scarce. A few years ago, foreign countries used virtual reality technology to rebuild the ancient Roman city, which deeply restored the ancient Roman city in history. With the help of virtual reality technology, tourists can watch the Colosseum in the ancient city of Rome and stroll through the ancient city. The VR version of Riverside Scene at Qingming Festival, exhibited by the Palace Museum, allows viewers to place themselves in the Riverside Scene at Qingming Festival just by watching the huge spherical screen on the couch. Universities at home and abroad have set up virtual reality technology laboratories on campus to study the application of VR in education, and enterprises have also developed classroom virtual reality teaching. The School of History of Beijing Normal University has set up a special course of history virtual simulation experiment.

3 Theoretical Basis

3.1 Constructivist Learning Theory

Constructivism learning theory emphasizes that students construct students' knowledge system through original experience or direct experience, and VR technology is a leader in visually displaying situations. By creating virtual problem situations, students' interest in learning can be stimulated, and students' cognitive needs can be generated. According to the survey, at present, the most mainstream practice is to upload the completed VR video courseware to the equipment. Students can intuitively see the original scene of historical events through the equipment in class, and under the explanation of history teachers, they can build their own historical knowledge system in their minds through the observed historical knowledge.

3.2 Embodied Cognition Theory

Embodied cognition theory specifically refers to the fact that people's sense of experience is closely related to their psychological feelings and influences each other. The cognitive concept advocated by the second generation of cognitive science is that cognition is embodied, situational, developmental and dynamic. Situational nature is closely linked with embodied nature, and the situational nature of embodied cognition is an inevitable criticism of the alienation of traditional cognitive mind. [2] According to embodied cognitive theory, teachers use VR technology to build a full learning scene in history teaching, and there is enough stimulation in the scene to guide students to generate positive emotional feedback on history teaching, thus improving students' learning effect.

4 The Application of Educational Meta-Universe in History

In the past history classroom, teachers used books as the media to spread knowledge, and blackboards and presentations as the tools to explain. The knowledge was so long that it was difficult for learners to understand, which could not satisfy learners' in-depth exploration of history knowledge. The history teaching based on meta-universe can make use of digital graphics system and various technical types of equipment, which can create a real-time interactive virtual environment and provide a real immersive classroom environment. In the past classroom videos, learners can only acquire knowledge by watching and listening. Metauniverse technology can make learners know the historical environment and knowledge at that time by touching and interacting, and as a member of Metauniverse in history classroom, they can participate in virtual scenes more.

In the past history classroom, teachers can only describe some abstract historical knowledge with words and figures, and the demonstrated content is quite different from the real content in history. Like some older buildings, cultural relics, primitive tribes, etc., no matter how many words and pictures are used to describe them, they are not vivid enough. History teaching in Metauniverse can restore these abstract contents through virtual reality technology, which can make students know the real history knowledge in a short time, thus improving the learning effect of students' history discipline.

According to the research status of Metauniverse in various disciplines in the field of education, this paper makes a feasibility analysis by combining relevant theories, the contents of historical disciplines and virtual reality technology, and concludes that three kinds of historical knowledge can be presented in the historical situation of Metauniverse through virtual reality technology, namely, cultural relics and historical monuments, historical events reappearance and virtual historical figures. The characteristics of historical subject knowledge are past, history can't be repeated or experimented, and abstract language can only be transformed into vivid pictures through existing technology. Therefore, the most difficult thing in the teaching process is to let students get a sense of historical experience and form a correct view of history. The advantage of combining virtual reality technology with history teaching to form history teaching meta-universe is that students can form real direct experience through sensory stimulation.

4.1 Restore Cultural Relics and Historical Sites

The knowledge of history contains a large number of historical relics, but teaching resources often appear in the form of words and pictures. For example, the bells of Zeng Houyi's tomb appeared in books. After reading the pictures, many students thought that the complete set of bells was about three meters long. In fact, the actual bells of Zeng Houyi's tomb were 7.48 m long. This set of chimes is kept in Hunan Provincial Museum. Students from schools near the museum can visit it, but more students can't observe it in person. Through virtual reality technology, scientific research workers can restore cultural relics perfectly and stereoscopically in the meta-universe, and learners can watch cultural relics at close range as a member of the meta-universe, and realize the same feelings as in real situations (Fig. 1).

Fig. 1. Bronze model of cultural relic two-headed peacock

In 2017, the Palace Museum adopted 3D scanning, virtual reality, panorama and other technologies to launch the Palace Museum VR Experience Hall. In addition, the National Museum of China, Zhangjiajie Museum, National Museum of London and other famous cultural relics museums all use virtual reality and other technologies to move cultural relics into the meta-universe. The study of cultural relics in the subject of meta-history (Fig. 2) through 3D scanning modeling, holographic image, virtual reality technology, augmented reality technology, combined with multimedia, audio explanation, graphic introduction, virtual simulation, real scene reproduction, human-computer interaction and other means, presents cultural relics to learners in all directions, which makes learners feel immersive and further deepens the impression of history study.

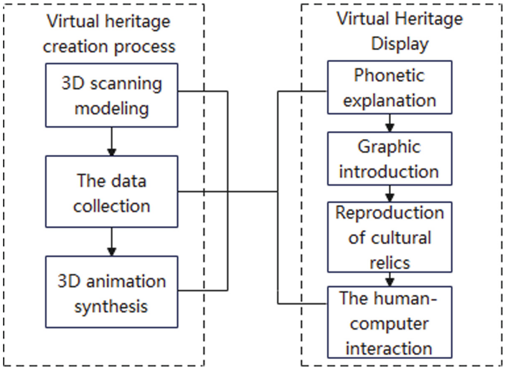

Fig. 2. Establishment and display process of virtual cultural relics

Through the technology of virtual reality, various historical sites can be vividly reconstructed in the meta-universe, so that the classroom teaching of history can break the limitation of time and space, reappear the history of hundreds, thousands or even tens of thousands of years ago in front of learners, and they can feel the ice age and the tribes where primitive people lived. As long as learners wear virtual reality equipment, they can enter the built historical meta-universe and become a part of it. They can visit all kinds of scenes of the virtual historical world in the meta-universe at close range and form profound cognition. While learners interact with the virtual historical environment, they can stimulate students' original knowledge system to integrate new knowledge and promote meaningful learning.

The reappearance of Mayan civilization in Central America is a representative case of the reappearance of historical sites in the meta-universe (Fig. 3). The project was founded by Professor Alexander Klippel of Pennsylvania State University, Park. The research focuses on immersion and spatial information theory, with the aim of creating a fully immersive program software for historical sites. In the production process, it is first necessary to visit the scene in Central America to capture the image of the motion structure map, take a panoramic image under the condition of sufficient light, and build a 3D model after making the image. Because of the horizontal distance between the eyes, the images formed on the retina are not completely consistent. After brain synthesis, we can distinguish the front, back, and distance of objects, thus producing stereoscopic vision effect.

Fig. 3. Maya ruins reconstruction program interface

4.2 Reenactment of Historical Events

In the process of history teaching, historical events are also important knowledge content. For example, the Opium War, the Revolution of 1911, etc. can't make learners understand the tragic war through simple words and pictures. Virtual reality technology can reproduce the historical moment at that time. Different from cultural relics and historical sites, when historical events are restored in the meta-universe, sound can be increased, showing dynamic visual effects, and learners' immersion is stronger. The reappearance of historical events requires a lot of time and cost, which is more difficult than other historical teaching resources.

Ji 'nan Zhixiang Leading Course makes five important historical events in modern Chinese history into a virtual simulation course, which uses two-dimensional pictures to make a large number of historical shots. In order to avoid the mixing of virtual scene operations and games in the meta-universe, the functions of answering questions and test papers are designed in the course, which pop up randomly during learners' learning, and interactive operations are set up, so that learners can better participate

Fig. 4. Experience VR virtual simulation movies in modern Chinese history

in history learning. The biggest advantage of applying virtual reality technology to history teaching is the reappearance of the original historical environment. The biggest difficulty in history teaching lies in how to make learners get "historical feeling" and form "historical sense". With the help of virtual reality technology, students' learning in the meta-universe of history teaching can be better integrated into historical scenes and have a deeper understanding of historical events (Fig. 4).

5 Virtual Historical Figures

Virtual reality technology can create personalized learning environment and make learners communicate with historical figures face to face. [3–15] Establish virtual historical figures in 3D modeling software, and place the figures in the corresponding historical scenes in the meta-universe. Students can interact with historical figures after entering the virtual historical scenes. Virtual characters can also be combined with cultural relics, historical sites and historical events in the meta-universe. For example, during the period of a hundred schools of thought, learners can talk with the great thinkers at that time and deeply understand the ideas represented by each school. Or the craftsman who created the cultural relics stood beside the cultural relics to tell the story of the cultural relics to the learners. Or put together poets of Tang and Song Dynasties who don't belong to the same period on the top of a famous building to recite poems with learners, so that learners can fully feel the poetry and painting of ancient poets. Learners and virtual historical figures participate in the history at that time, and it is easier to bring themselves into the scene, so as to understand the mood of historical figures.

In the "VR Experience Hall of the Forbidden City" project launched by the Palace Museum, the experiencer can experience the "Zhu Di Zhao Jian Forbidden City" project with the help of VR 4D helmet with the help of virtual reality technology(Fig. 5),and feel the horse riding and sightseeing in the Forbidden City with Zhu Di, emperor of the Ming Dynasty.

Fig. 5. VR Experience Museum of the Palace Museum

In the history course, a lot of knowledge can be displayed through the virtual scenes in the meta-universe. Only by letting learners really integrate into history learning can students be more willing to take the initiative to explore, understand and learn history.At the same time, the corresponding exercises can be implanted in the demonstration process, so that learners can consolidate what they have learned and achieve twice the result with half the effort.

6 Summary

The curriculum standard of history requires learners to understand and master knowledge, and be able to apply knowledge to solve problems creatively. Before combining virtual reality technology with history teaching in meta-universe, it is necessary to do feasibility analysis. Some simple knowledge and attempts can be accomplished through ordinary classroom teaching, while some abstract knowledge can help learners understand the history at that time with the help of virtual scenes, and construct their own knowledge through the direct experience gained.

Virtual historical scenes can also promote learners' ability to express and summarize. After meta-universe history teaching, students need to summarize and describe the reappeared historical events and make corresponding evaluations of historical figures. In the process of communication and cooperation between teachers, students and students, students' thinking ability can also be improved. In the communication and cooperation between teachers and students, students can also improve their ability to think about problems. Teaching history in the form of meta-universe can improve learners' interest in history, stimulate learners' cognitive drive and improve learners' learning effect. In the process of implementation, learners can participate in the learning process, form self-control, and produce positive transfer effect for other disciplines.

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A Multilevel Mediation Study on the Effects of ICT Self-efficacy on Adolescents' Digital Reading Performance

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Abstract. The present study investigates the effects of information and communication technology (ICT) self-efficacy on 15-year-old students' digital reading achievement, along with the potential mediating role of using ICT at school. Multilevel mediation modelling was adopted to analyze data from the publicly available Programme for International Student Assessment (PISA) 2018 database, encompassing 14,273 students aged 15 from 763 schools in Australia. Two main results were found: (1) the positive effects of ICT self-efficacy on digital reading scores existed; (2) ICT use at school mediated such a correlation and suppression effects were found. The results shed light on the improvement of digital reading performance by promoting students' ICT self-efficacy level and striking a balance between ICT-related attitudinal and behavioral factors in educational practice.

Keywords: Mediation Analysis · ICT Self-efficacy · ICT Use · Digital Reading · PISA

1 Introduction

Users of information and communication technology (ICT) and digital readers have been on the rise in the increasingly digitalized world and the post-COVID-19 pandemic era [1]. Such a new learning environment necessitates students to master unique reading skills on digital platforms involving novel text types and sociocultural activities [2, 3] so that they could participate in intellectual, social, and occupational interaction and collaboration in a society undergoing rapid digitalization [3, 4]. To capture the evolving essence of reading from the traditional to the digital one, the Programme for International Student Assessment (PISA) redefined reading performance in its latest cycle, PISA 2018, and conducted a large-scale computer-based reading assessment. Based on the new assessment framework of PISA, in this study, digital reading performance was defined as the capacity of text comprehension, usage, evaluation, reflection, and engagement on digital platforms for knowledge acquisition and goal attainment as a qualified citizen [5].

In studying the significant factors that have great impacts on students' digital reading performance, previous studies have preliminarily identified several ICT-related attitudinal and behavioural factors, such as self-efficacy and frequency of using digital devices.

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ICT self-efficacy, as defined by the ICT engagement model based on self-determination theory (SDT) [6], refers to students' self-perception of their own ICT knowledge and skills. However, prior research has yielded conflicting results regarding the correlation between this factor and digital reading achievement, mostly positive but several negative [7, 8]. With respect to ICT use, although several studies have found that using ICT at school imposed negative effects on teenagers' digital reading achievement [8, 9], considering the rapid development of ICT and digital reading activities, the data used by previous studies need updating, and the sample size could be enlarged. Most importantly, the mechanism underlying the relationship between ICT self-efficacy and students' performance in digital reading tasks and the potential role of using ICT at school remain largely uninvestigated, even though ICT use and ICT self-efficacy were interrelated both theoretically [6] and empirically as previous studies revealed [8].

Exploration of how ICT self-efficacy and use influence students' performance in computer-based reading tasks could further the understanding of the underlying mechanism, inform educational theory, assist educators in guiding adolescents to treat and utilize ICT adequately, distinguish the disparities in reading performance [10], and develop pedagogical and administrative practices involving the use of ICT [11, 12].

Therefore, the current study aims to investigate how ICT self-efficacy influences adolescents' digital reading achievement and elucidate the potential indirect effect of ICT use at school. Specifically, multilevel mediation modelling was utilized to analyze the data of Australia from the PISA 2018 database, controlling for demographic information. Accordingly, two research questions were addressed: (1) Are ICT self-efficacy and adolescents' reading performance on digital platforms positively or negatively correlated? (2) To what extent are the effects of ICT self-efficacy mediated by the frequency of using digital devices at school?

2 Methodology

2.1 Sample

The data were retrieved from the publicly available database of the latest PISA cycle, PISA 2018 (URL: http://www.oecd.org/pisa/data/2018database/). Conducted by the Organisation for Economic Co-operation and Development (OECD), PISA is a large-scale educational survey assessing students' academic performance at the age of 15. To attain relatively representative results, this study adopted the data from Australia, which encompassed the largest available sample among OECD countries/economies attending the digital reading assessment and completing the optional ICT Familiarity Questionnaire. In total, available samples included 14,273 15-year-old students (female = 7,075) from 763 schools in Australia.

2.2 Materials and Instruments

The data were retrieved from the publicly available database of the latest PISA cycle, PISA 2018 (URL: http://www.oecd.org/pisa/data/2018database/). Conducted by the Organisation for Economic Co-operation and Development (OECD), PISA is a large-scale educational survey assessing students' academic performance at the age of 15. To

attain relatively representative results, this study adopted the data from Australia, which encompassed the largest available sample among OECD countries/economies attending the digital reading assessment and completing the optional ICT Familiarity Questionnaire. In total, available samples included 14,273 15-year-old students (female = 7,075) from 763 schools in Australia.

Variables. As Table 1 showed, the dependent variable was digital reading performance, represented by ten plausible values (PVs). The independent variable was ICT self-efficacy represented by the variable coded as EFFICT and generated from five questions, denoting students' self-perception of their competence in completing tasks with digital devices. The EFFICT scale reliability, computed by PISA using item response theory (IRT), was 0.864, demonstrating acceptable internal consistency. The potential mediating variable was students' ICT use at school coded as USESCH, derived from ten Likert scale questions regarding how frequently students participated in ICT activities in the formal learning context. Additionally, two control variables were used throughout the modelling: students' gender represented by a dummy variable with female = 1 and socio-economic background (ESCS).

Table 1. The variable description and descriptive statistics

Variable codes	Description	Mean	SD
Dependent variable			
READ	Digital reading performance represented by 10 PVs	502.8597	108.7629
Independent variable			
EFFICT	ICT self-efficacy	0.1311	0.8178
Mediating variable			
USESCH	ICT use at school	0.3753	0.7252
Control variable			
Gender	gender	0.5043	0.5000
ESCS	Students' socio-economic and cultural background index	0.2866	0.8727

[a]The data source is PISA 2018 database

Statistical Analysis. With respect to data preprocessing, missing data were treated with the expectation maximization imputation method in SPSS 20.0 [13]. Multicollinearity problem was excluded by computing the correlation matrices. The final student weight was adopted in this study.

Multilevel mediation modelling was applied to examine how ICT self-efficacy influence 15-year-olds' computer-based reading performance and the potential mediating effects of using ICT at school. The mediation analysis refers to the regression-based investigation of the extent to which the dependent variable (Y) was affected by the independent variable (X) through the mediator (M) [14], as Fig. 1 illustrated. The current study is mainly concerned with the total effect (path *c*) and the indirect effect (i.e., mediating effect, path *ab*).

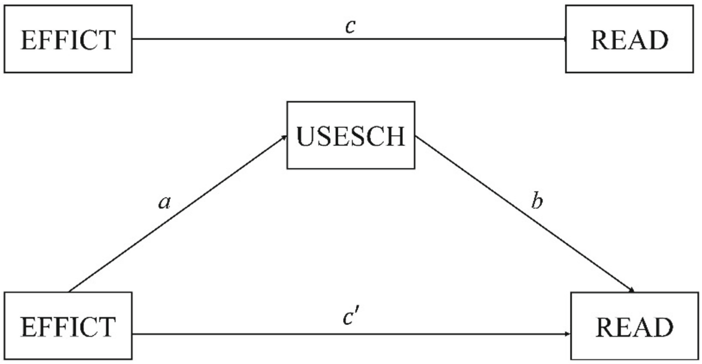

Fig. 1. The mediation model of this study

To address the nested data structure of the PISA database [5], multilevel mediation was adopted, which could explain the significant percentage of between-school variances, achieving risk reduction of statistical errors [15]. Specifically, 1–1-1 multilevel mediation modelling was employed in which all the variables were student-level variables. Additionally, to prevent potential confounding, group mean centering was applied to X and M, with the aggregated mean reintroduced to the equations at the school level [16], though the within-school effects were the focus of this study. The appropriateness of data aggregation of M was confirmed as the following parameters demonstrated: $r_{wg(j)} = 1$, intraclass correlation coefficient (ICC) = 0.13, $x^2 = 2{,}809.83$ ($p < 0.001$) [17, 18].

The statistical programme HLM 8 was used to construct the multilevel mediation model. After model assumptions-checking [15], the model was built step by step [16]. Each PV was employed as the dependent variable in every single run of the model, and then data pooling on the basis of Rubin's rules [19] was applied to the final results based on 10 PVs. The indirect effects were tested by joint significance [14] accompanied by calculating Monte Carlo confidence intervals [20, 21] with RMediation [22] package in R. The indicator of the effect size was the proportion mediated (PM), which refers to the percentage of the mediating effect in the total effect [23].

3 Results

Multilevel modelling was first confirmed to be necessary through an intercept-only empty model with no independent variable. By computing the percentage of the variance explained respectively by the student- and the school-level variables [15], ICC was obtained. As shown in Table 2, the value of ICC was 0.18, higher than 0.138 thus indicating high intraclass correlation [24] and confirming the need for multilevel modelling.

Table 2. The ICC of the empty model

	Within-school variance	Between-school variance	ICC
Value	9,642.10	2,182.06	0.18

Second, the total effect was examined by constructing a model with random intercept and fixed slope controlling for Gender and ESCS, in which READ was the dependent variable, EFFICT was the independent variable. As shown in Table 3, the model coefficient for total effect was significantly positive ($B = 12.85$, SE = 1.29, $p < 0.001$), which indicated when self-efficacy increases by 1 unit, students gain a 12.85-points increase in their digital reading performance. Additionally, for the control variable student gender, the coefficient was significantly negative ($B = -31.14$, SE = 2.04, $p < 0.001$), indicating that male adolescents generally have a lower level of digital reading performance than their female counterparts. For ESCS, a significantly positive coefficient exists ($B = 26.08$, SE = 1.44, $p < 0.001$), suggesting that higher-level household socio-economic and cultural backgrounds tend to render higher digital reading scores.

Following the total effect model, two sets of models were built subsequently to investigate the direct and mediating effect of EFFICT on READ. As shown in Table 3, the coefficient for the direct effect was significantly positive ($B = 19.83$, SE = 1.43, $p < 0.001$).

As suggested by the model coefficient of the mediating effect, confidence interval, and the effect size value presented in Table 3, USESCH is a significant mediator. Primarily, PM was adopted to compute the effect size. However, after detecting the suppression effect in this study, i.e., a particular type of mediation when the signs for the direct and mediating effects were opposite [25], the absolute value of the percentage of the mediating effect in the direct one was adopted as the effect size indicator [26]. The threshold of the effect size for small effect is 0.10, for medium is 0.30, and for large is 0.50 [24]. As shown in Table 3, the effect size implied a small to medium effect, i.e., the mediating role of using ICT at school exists.

Table 3. The total, direct, mediating effects, and effect size in the mediation modelling

	Total		Direct		Indirect		Effect size
	B	SE	B	SE	ab (95% CI)	SE	
Value	12.85	1.29***	19.83	1.43***	−3.48 (−4.37, −2.64)	0.44	0.18

[a]***: $p < 0.001$.

[b]Confidence intervals not containing zero are deemed significant.

4 Conclusions and Discussions

Having witnessed more frequent ICT use and digital reading activities during the post-COVID-19 era, the current study explored the means by which adolescents' ICT self-efficacy influences computer-based reading performance and examined the mediating effects of ICT use at school.

Research question 1 explored the effects of ICT self-efficacy. Findings revealed a significantly positive relationship between self-perception of ICT ability and computer-based reading performance based on 14,273 adolescent students from Australia. Theoretically, such a finding resonates with the SDT-based ICT engagement model [27], which proposed that high ICT self-efficacy might generate greater performance in learning tasks involving ICT use. Empirically, the positive results were in line with previous studies [7, 28], demonstrating better digital reading performance among the adolescents deeming themselves to be competent using ICT than their unconfident counterparts. Such a finding has several possible reasons. First, previous researchers have revealed that perceiving oneself as competent in performing ICT-related activities might lead to better performance in ICT-related tasks [29]. Thus, ICT self-efficacy might boost digital reading performance by improving ICT-related task performance. Furthermore, students perceiving themselves as highly competent in ICT tasks might be more relaxed in the PISA digital reading assessment environment, enabling them to focus more on the reading task than on the test environment [30].

Research question 2 explored the existence and the extent of the mediation of ICT use frequency at school. Findings indicated that mediation existed. Specifically, a small to medium proportion of the influence of ICT self-efficacy was mediated through ICT use at school. Furthermore, the suppression effect, a particular type of mediating effect, was revealed in this study. Although adolescents considering themselves competent in ICT-related tasks were more likely to gain higher digital reading scores, the positive effects of ICT self-efficacy tended to decrease when ICT use at school was considered meanwhile. In other words, the positive influence of ICT self-efficacy was offset by using ICT at school. This dynamic balance could be explained in two aspects. First, empirically, the negative influence of using ICT at school was in alignment with previous findings [28, 31]. Second, although students who are more confident in their ICT skills might be more active in ICT-related activities, they might unconsciously inflate their ICT abilities [32], which might lead to poor digital reading performance.

These findings provide the following pedagogical implications for improving digital reading education. First, the present study confirmed the role ICT self-efficacy played in differentiating adolescents who performed better in digital reading assessments from those who did worse. Therefore, adequate measures need to be taken at school and at home to boost students' confidence in their ICT competence, for instance, by building a competence-supportive environment in both formal and informal learning contexts [33] to help satisfy students' basic psychological needs for competence [34]. Second, the suppression effect, as the findings revealed, indicated that to improve digital reading performance, simply enhancing ICT self-efficacy is not enough. Instead, the underlying effects of ICT use at school need cautious treatment. Further studies could explore the reasons for the negative impacts of using ICT at school to develop relevant measures to counteract such effects. For instance, efforts could be made to regulate students' ICT use in classrooms [35]. In this way, the positive effects of ICT self-efficacy on digital reading performance could be effective and efficient.

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Deep Knowledge Tracking Method Based on DKVTMN-DTCN Model

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Abstract. With the rapid development of deep neural networks, deep knowledge tracking models have become one of the most important research areas in educational data mining. While most knowledge tracking models assume that the forgetting level of all students is constant, in reality, forgetting levels are affected by time intervals and different learning abilities. The learning ability of the same student changes over time, and there is variability in the learning ability of different students, so students will forget their knowledge to different degrees within the same time interval of answering questions. The DKVMN-DT uses CART to preprocess student behavioral characteristics. However, the time series analysis capability of the decision tree model is very limited, and the prediction results it obtains are basically within a certain training range, so for features with the significant trend, the decision tree cannot directly predict the time series changes in student behavior. In summary, a DKVTMN-DTCN knowledge tracking model that combines a temporal forgetting mechanism based on a priori student ability and automatically extracts temporal features using temporal convolutional networks is proposed to capture students' long-term behavioral characteristics and personalize knowledge forgetting. Experimental results show that the prediction performance of the DKVTMN-DTCN is significantly improved compared with the classical model on both datasets.

Keywords: knowledge tracking · decision tree · deep learning · temporal convolutional network · dynamic key-value memory network

1 Introduction

With the rapid development of intelligent information technology and the background of the Corona Virus Disease 2019, traditional offline teaching is gradually transformed into online teaching. Online education system provides a good learning platform for the public, and at the same time, educational data mining has become an inevitable condition for providing personalized education for students. Knowledge tracking is one of the powerful tools to achieve artificial intelligence-assisted education [1].

The purpose of knowledge tracking is to predict students' knowledge level by tracking their historical answers. Its mathematical form can be described as follows: assume that given a sequence of student observations $\{x_0, x_1, \cdots, x_t\}$, x_{t+1} is the predicted student learning at moment $t+1$. Where $x_t\{q_t, r_t\}$ denotes the student's practice label q_t at moment t and the answer r_t.

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Knowledge tracking can be broadly classified into Bayesian knowledge tracking and Deep knowledge tracking. The powerful characterization ability of deep learning has prompted more scholars to devote themselves to the research of deep learning based knowledge tracking. Among them, the representative models are Deep Knowledge Tracing (DKT) [2], which is based on recurrent neural network (RNN), and Dynamic Key-Value Memory Networks (DKVMN) [3], which uses key-value matrix to track students' knowledge state. And to address the problem of missing learning features in these models, Sun et al. [4] proposed DKVMN-DT based on CART behavioral feature preprocessing. However, this makes them ignore the impact of the time-series nature of the features on the learning process; the time series of learning behaviors reflect the specific efforts performed by students in various aspects of the learning process, and CART requires a lot of preprocessing work when processing data with temporal order. The methods commonly used today for processing time series features may change the length of the series and are not suitable for performing the analysis of learning behavior patterns. Bai et al. [5] found that temporal convolutional networks are more effective in dealing with time series problems through experiments and analysis of temporal convolutional networks. Introducing temporal convolutional networks into knowledge tracking models to process time series features better captures students' long-term learning behaviors and more accurately tracks students' knowledge states. In addition, most models always keep students' knowledge states constant or show shallow forgetting when data are missing or the time interval between answer records is large. This makes the knowledge tracking models fail to truly reflect the learning situation and forgetting pattern of different students' abilities. Therefore, we add an enhanced forgetting time effect mechanism based on learning ability to enhance the effect of large time intervals on students' knowledge states, so that the knowledge tracking model can be more consistent with the forgetting time law of student learning.

In summary, this paper proposes a knowledge tracking model DKVMN-TCN based on temporal features and enhancing the time effect of forgetting under different learning abilities. The main work of this paper is as follows:

- The use of TCN to deal with the temporal characteristics of students' behavior is proposed. Effectively enhancing the model's ability to analyze students' long-term behavioral characteristics.
- An enhanced forgetting time effect mechanism based on a priori learning ability is added to enhance the effect of different learning abilities and large time intervals on forgetting.
- The DKVTMN-DTCN model is compared with the classical models DKT, DKVMN, and DKVMN-DT on two datasets, and the experimental results show that our model has better prediction performance.

2 Related Work

With the rapid development of deep learning, deep neural networks are widely used in various fields of artificial intelligence [6–8]. In recent years, in addition to the classical DKT, a highly representative one is the Dynamic Key-Value Memory Network

(DKVMN) proposed by Zhang et al. [3]. The main feature of this model is the use of a pair of key-value matrices as the memory structure. The static key matrix stores the student's knowledge concepts and the dynamic value matrix stores the student's knowledge states. DKVMN uses discrete exercise tokens and associates the exercises with each potential concept through a simple attention mechanism. Finally, the response probability $p(r_t|q_t)$ is obtained while the student knowledge state is updated.

Temporal convolutional network (TCN) was proposed by Bai et al. [5] in 2018, which is a special structured convolutional neural network model, a novel network model obtained by combining both causal convolution, dilated convolution and residual linkage based on traditional one-dimensional convolutional neural network. In recent years, this model has achieved excellent results in machine translation, natural language processing and other fields.

3 Method

DKVTMN-DTCN mainly consists of an input layer, a feature processing layer, and a predictive output layer. As shown in Fig. 1. The input layer has two parts, which are temporal feature data and non-temporal feature data. The feature processing layer is mainly a temporal feature processing module and a non-temporal feature processing module, the former uses temporal convolutional network to process temporal features; the latter uses CART to process non-temporal features. Finally, we added a feature linking module and an enhanced forgetting time effect mechanism based on learning ability in the prediction output layer with DKVMN as the baseline to predict student answers.

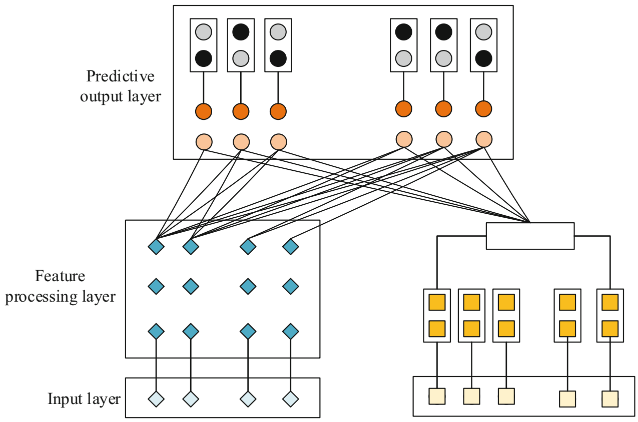

Fig. 1. DKVTMN-DTCN model structure, the diamond indicates the processing of temporal features, the rectangle indicates the processing of non-temporal features, and the circle indicates the prediction output layer.

3.1 Input Layer

The input layer is mainly one-hot encoding of temporal feature data and non-temporal feature data for efficient processing of feature data.

3.2 Feature Processing Layer

The feature processing layer mainly consists of two parts, the first part is to take advantage of the powerful parallelism, flexible perceptual field, stable gradient and low memory of TCN to deal with the time-series problem, and the second part is to take advantage of the relatively small computation and easy understanding of CART to deal with the non-time-series problem.

1) The temporal feature processing module mainly consists of causal convolution, inflation convolution, and residual concatenation. The causal convolution, with each layer at moment t, can only obtain the historical data at moment t of the previous layer and before, and cannot use future data such as t + 1. This feature makes the model particularly suitable for dealing with time series problems. When the length of the sequence to be processed is particularly long, a particularly large number of convolutional operations is required, which can greatly increase the computational effort, and to address this problem, the network structure is extended by using the expanded convolutional field. Also, to effectively alleviate the problem of gradient disappearance and gradient explosion in convolutional networks with deeper layers and to enable the network to retain the original important information, a residual module is added. The residual connection is the input x of the residual unit added to the output $f(x)$ to model the network: $f(x) + x = o(x)$. This makes the network more stable, as shown in Fig. 2.
2) The non-temporal feature processing module analyzes the non-temporal features using the CART with low computational overhead, suitable for large data, and interpretable features. The input of this module is the binary data of non-temporal features and the output is the decision tree prediction result.

3.3 Predictive Output Layer

The prediction output layer mainly uses DKVMN to track the students' knowledge state and predict the students' answers. DKVMN, as a classical deep knowledge tracking model, uses a pair of key-value matrices to store and track the topic knowledge concepts as well as the students' knowledge state.

However, two important issues need to be considered when inputting the processed data from the feature processing layer to the prediction output layer: first, how to ensure the consistency of data dimensionality and sample size of these two datasets at the time of input; second, students may forget or increase their knowledge at intervals of minutes, hours, or days before answering the next question, and students have different learning abilities, which can directly lead to different levels of forgetting at different time intervals for different students.

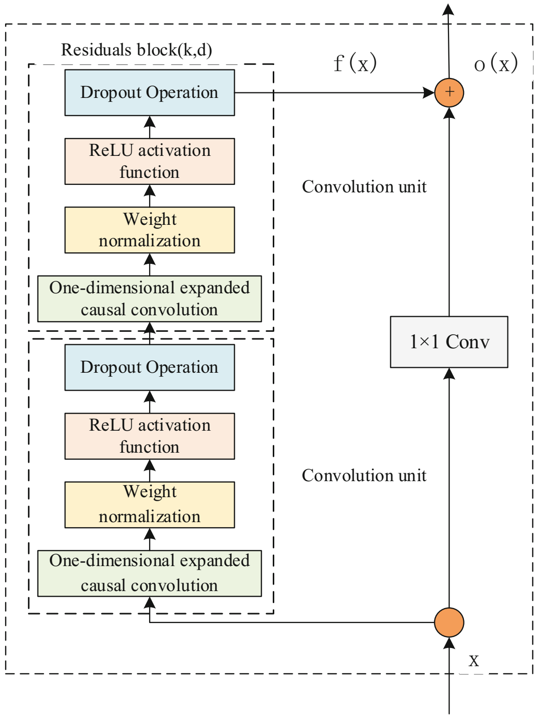

Fig. 2. TCN Residual Unit. The residual unit contains two convolution units and a nonlinear mapping.

To address these two issues, we set up a feature-connected module in the input stage to address the inconsistency of data input. Initial learning ability is calculated and learning interval timestamps are added during the writing process to enhance the effect of large time intervals on students' knowledge states at different learning abilities and different responses to forgetting mechanisms in the model. The structure of the prediction output layer is shown in Fig. 3.

The feature concatenation module: Crosses the temporal a priori data with the non-temporal a priori data and then uses the crossed features as the final input.

$$\boldsymbol{c}(\mathrm{q_t,g_t}) = \boldsymbol{f}(\boldsymbol{G}_t, \boldsymbol{T}_t) \tag{1}$$

where $\boldsymbol{c}(q_t, g_t)$ is the crossover feature, including the preliminary prior data corresponding to the student. $\boldsymbol{f}(\cdot)$ denotes the join operation, which is implemented using the concatenate function in the Keras model. $\boldsymbol{G}_t$ denotes the non-temporal prior result. $\boldsymbol{T}_t$ denotes the temporal prior result.

The simple one-way attention mechanism is mainly reflected in $\boldsymbol{w}_t$:

$$\boldsymbol{w}_t(i) = soft\max(\boldsymbol{c}_t \boldsymbol{M}^k(i)) \tag{2}$$

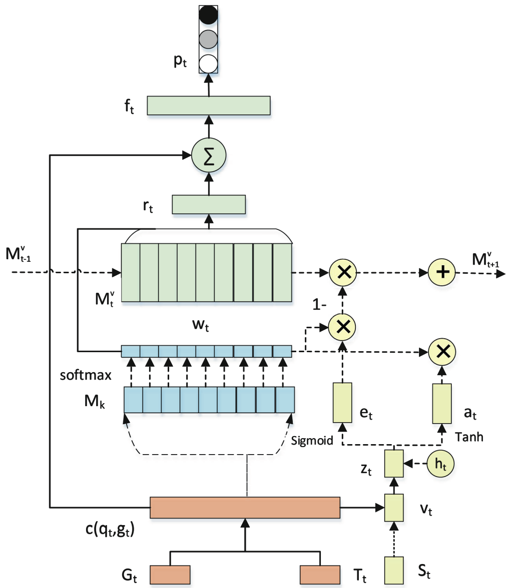

Fig. 3. Structure of the prediction output layer, orange indicates the feature connection module, blue indicates the simple one-way attention mechanism, green indicates the reading process, and yellow indicates the writing process. (Color figure online)

where the static matrix ($\boldsymbol{M}^k$) is of size $N \times \boldsymbol{d}_k$ and the data it stores is the potential concept information. The weight vector $\boldsymbol{w}_t$ represents the correlation between the exercise and each potential concept.

The reading process focuses on probabilistic prediction of answer situations by analyzing conceptual information and outputting the predicted probabilities as results.

$$\boldsymbol{\gamma}_t = \sum\nolimits_{(i=1)}^{v} \boldsymbol{w}_t(i)\boldsymbol{M}_t^v(i) \tag{3}$$

$$\boldsymbol{f}_t = \text{Tanh}(\boldsymbol{w}_1^T[\boldsymbol{\gamma}_t, \boldsymbol{c}_t] + \boldsymbol{b}_1) \tag{4}$$

$$p_t = sigmiod(\boldsymbol{w}_2^T \boldsymbol{f}_t + \boldsymbol{b}_2) \tag{5}$$

where $\boldsymbol{\gamma}_t$ is a summary of the student's mastery of the exercise. The summary vector $\boldsymbol{f}_t$ contains the student's level of knowledge and the difficulty of the questions as well as the learning characteristics. Finally, the p_t scalar is obtained, which is the probability that the student answered $\boldsymbol{q}_t$ correctly.

The writing process is mainly an operation to update the students' knowledge status. Before that, we first calculate the correct answer rate and wrong answer rate based on the a priori results obtained from preprocessing, and use the difference as the students' a priori learning ability, and make different forgetting responses according to students' different learning ability and learning time interval.

$$\boldsymbol{R}(x)_t = \sum_{i=1}^{k} \frac{x_i == 1}{|N|} \tag{6}$$

$$\boldsymbol{I}(x)_t = \sum_{i=1}^{k} \frac{x_i == 0}{|N|} \tag{7}$$

$$\boldsymbol{S}(x)_t = \boldsymbol{R}(x)_t - \boldsymbol{I}(x)_t \tag{8}$$

where $\boldsymbol{R}(x)_t$ denotes the correct answer rate of students doing k question, $\boldsymbol{I}(x)_t$ denotes the incorrect answer rate of students doing k questions, $|N|$ denotes the total number of questions done by students, $x_i = 1$ denotes correct answers by students, $x_i == 0$ denotes incorrect answers by students, and $\boldsymbol{S}(x)_t$ denotes the learning ability of students.

We also set the learning interval timestamp $\boldsymbol{h}_t$ during the writing process, and $\boldsymbol{h}_t$ is the timestamp of the binary vector. The format is "%Y-%m-%d %H:%M:%S", which is then divided by the scale factor α and converted to a 16-bit binary vector. This setting enhances the robustness of the large time interval between input exercises. The write process is divided into two main operations, namely, erasing memory and adding memory. Erasing memory represents the process of student forgetting of knowledge concepts:

$$\boldsymbol{v}_t = \boldsymbol{B}[\boldsymbol{c}(q_t, g_t), \boldsymbol{S}_t] + \boldsymbol{b}_3 \tag{9}$$

$$z_t = \boldsymbol{w}_3[\boldsymbol{v}_t, \boldsymbol{h}_t] + \boldsymbol{b}_4 \tag{10}$$

$$\boldsymbol{e}_t = sigmoid(\boldsymbol{E}^T z_t + \boldsymbol{b}_e) \tag{11}$$

$$\tilde{\boldsymbol{M}}_t^v(i) = \boldsymbol{M}_{t-1}^v(i)[1 - \boldsymbol{w}_t(i)\boldsymbol{e}_t] \tag{12}$$

where $\boldsymbol{v}_t$ denotes the knowledge growth of students with different learning abilities after completing this exercise. $\boldsymbol{B}$ denotes an embedding matrix of size $(2\boldsymbol{Q} \times \boldsymbol{d}_v)$. z_t is a vector of knowledge growth with enhanced time effects. $\boldsymbol{e}_t$ denotes the erasure memory vector, and $\boldsymbol{E}(\boldsymbol{d}_v \times \boldsymbol{b}_e)$ is the transformation matrix.

Increasing memory indicates the update of students' knowledge of relevant concepts through exercises and answers to questions:

$$\boldsymbol{a}_t = \mathrm{Tanh}(\boldsymbol{D}^T z_t + \boldsymbol{b}_a)^T \tag{13}$$

$$\boldsymbol{M}_t^v(i) = \tilde{\boldsymbol{M}}_{t-1}^v(i) + \boldsymbol{w}_t(i)\boldsymbol{a}_t \tag{14}$$

where $\boldsymbol{a}_t$ is a row vector, i.e., an increasing memory vector, and this mechanism of erasing before adding corresponds to the state of knowledge change in which students forget and reinforce concepts during the learning process.

4 Experiment

4.1 Datasets

In this paper, we focus on two publicly available real datasets ASSISTments2012 [9] and Algebra2005–2006 [10] for comparison experiments.

ASSISTments2012: This dataset comes from the data of ASSISTments online education platform in 2012. Due to the large size of this dataset, the data of students with less than 3 records and empty skill labels were removed, and 5000 students were extracted from the data. The final data consisted of 5,000 students answering 94,0179 exercises and 242 different exercise labels. The filtered experimental characteristics data are shown in Table 1.

Table 1. Assistments2012 Dataset Feature Classification

Feature Type	Feature Tags	Content
Timing characteristics	Start_time	Start Time Stamp
	End_time	End Time Stamp
	Ms_first_response	Time of first response
	First_action	Type of the first operation
Non-chronological characteristics	Problem_id	ID of the question
	User_id	ID of the student
	Skill_id	ID of the skill
	Hint_count	Number of tips for questions
	attempt_count	Number of attempts to answer questions
	Bottom_hint	Whether to request all tips

Algebra 2005–2006: This dataset is from the development dataset of the KDD Cup 2010 Educational Data Mining Challenge. It includes a total of 575 students answering 813,661 steps. The data of the experimental characteristics after passing the screening are shown in Table 2.

4.2 Experiment Setting

The prediction performance of the model is evaluated using two evaluation metrics, the average AUC and the average ACC. We extract 80% of the dataset as the training set and 20% as the test set. Each comparison model and experimental parameters are set as follows.

- **DKT**: A recurrent neural network was used as the basic structure to interpret the hidden states as the student's knowledge states. The experiments use the hyperparameters set

Table 2. Algebra 2005–2006 Dataset Feature Classification

Feature Type	Feature Tags	Content
Timing characteristics	Step Start Time	Start Time
	Step End Time	End Time
	Error Step Duration	Duration of the first error attempt
	Correct Step Duration	First attempt for the correct duration
	Correct First Attempt	The right first attempt
Non-chronological characteristics	Anon Student Id	Anonymous identifier for students
	Problem Name	Unique identifier for the issue
	Skill_id	Each question consists of one or more skills
	Corrects	Total number of correct attempts
	Incorrects	Total number of error attempts
	Hints	Total number of request alerts

by Piech et al. [2]. The hidden layer size is 200, the batch size is 30, the learning rate is 0.001, and the Adam optimizer is selected.

- **DKVMN**: Prediction of students' answers using a simple attention mechanism and a key-value memory matrix. The hyperparameters set by Zhang et al. [3]. Were used in the experiments. To reduce the number of parameters, we set dk = dv, so the dimensions of the static key memory matrix and dynamic value memory matrix are chosen among {10, 50, 100, 200}, the batch size is 30, the learning rate is 0.001, and the Adam optimizer is selected.
- **DKVMN-DT**: The behavioral characteristics of students are preprocessed using the CART algorithm and combined with the DKVMN. The initial parameters of this model are randomly generated using a Gaussian distribution with mean 0. The batch size, learning rate and optimizer selection are the same as those of the DKVMN.
- **DKVTMN-DTCN**: Take advantage of the strong advantage of TCN in processing temporal feature data and add a temporal forgetting mechanism based on a priori student ability to DKVMN-DT. In this paper, the model is compared by experimental tests and found that the best prediction effect is achieved when the convolutional kernel size is 6, the dropout ratio is set to 0.1, the dilation factor d = 2n, n is initialized to 0, and increases with the increase of residual blocks. The batch size is 32, the learning rate is 0.002, the Adam optimizer is used, and the number of training iterations is 100.

4.3 Comparison of Experimental Results

The results obtained from the comparison experiments are shown in Table 3, and the DKVTMN-DTCN in this paper outperforms the original model in terms of AUC and ACC on both public datasets. And three conclusions can be analyzed from the experimental results.

Table 3. Experimental Results of Comparing Deep Knowledge Tracking Models

Dataset	Evaluation Indicators	DKT	DKVMN	DKVMN-DT	DKVTMN-DTCN
ASSISTments2012	AUC	72.68	73.42	74.55	75.93
	ACC	6813	68.78	68.91	70.17
Akgebra2005–2006	AUC	76.59	77.32	78.43	79.08
	ACC	69.11	69.57	69.94	70.25

- DKVMN-DT and DKVTMN-DTCN achieved better AUC performance and better prediction accuracy than DKT and DKVMN by adding CART decision trees to preprocess students' behavioral features. This is mainly because behavioral features contain information about students' learning ability performance. For example, the student's mastery of the knowledge from whether to ask for help or hints, and the student's proficiency from the number of attempts to answer a question can be uncovered. Moreover, CART decision trees can generate easy-to-understand rules and relatively small computational effort when processing classification features.
- In both datasets, DKVTMN-DTCN has a clear advantage over DKVMN-DT in terms of average AUC value and average ACC value. The disadvantages of the CART decision tree algorithm used in DKVMN-DT preprocessing are that it requires more preprocessing work when dealing with time sequential data and errors may increase faster when there are too many categories. The advantages of the temporal convolutional network TCN, on the other hand, are parallelism when dealing with time-series problems, stable gradients, flexible perceptual fields, and the use of lower memory. Combining TCN with DKVMN and applying it to process data with time-series characteristics, and combining the advantages of CART decision trees in processing non-time-series problems that are easy to understand and computationally small, better prediction performance is achieved.
- DKVTMN-DTCN incorporates a temporal forgetting mechanism based on a priori student ability, and it achieves a more significant advantage over DKVMN in both comparison experiments of the two datasets. The reason for this is that the different learning abilities of students lead to different levels of understanding of knowledge and different levels of forgetting in the large time interval between the next answer to the question. Therefore, the average AUC performance as well as the average ACC performance of DKVTMN-DTCN is better in the probability prediction performance of different students.

4.4 Analysis of Time Forgetting Module Based on Learning Ability

To verify the temporal forgetting mechanism based on learning ability incorporated in the writing process of this paper, we conducted control variable experiments on the DKVTMN-DTCN proposed in this paper in the ASSISTments2012 dataset. In the experiments, we calculate students' a priori learning ability by preprocessing different students' behavioral characteristics and classifying students' abilities into 11 segments. Because the intervals in the data set ranged from a few minutes to several days, the length of the horizontal axis was reduced by log2 (time) in this paper. The experimental results are shown in Fig. 4, which shows the heat map of the degree of students forgetting for different learning abilities at different time intervals. From the figure, it can be seen that the stronger the learning ability, the lower the degree of forgetting at the same time interval, and the longer the time interval, the higher the degree of forgetting at the same learning ability. It can be seen that the degree of forgetting of students is closely related to learning ability and time interval, which proves the feasibility and effectiveness of the time forgetting mechanism based on learning ability in the model of this paper.

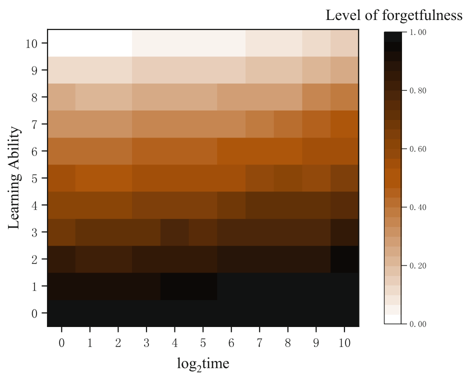

Fig. 4. Heat map of temporal forgetting based on learning ability, the higher the forgetting level, the darker the color. The lower the forgetting level, the lighter the color.

4.5 Timing Feature Processing Module Analysis

To verify the effectiveness of the temporal convolutional network used in the temporal feature processing module, this section uses DKVMN-DT as the baseline and adds TCN for experimental analysis. The experimental procedure uses the ASSISTments2012 dataset, and the results are shown in Fig. 5. The average AUC value and the average ACC value of DKVMN-DTCN are 0.64% and 0.73% higher than those of DKVMN-DT, respectively.

In this paper, six answer records of four students for three knowledge points and the corresponding behavioral feature data are randomly selected in the dataset, and the prediction performance of this data in DKVMN-DT and DKVMN-DTCN, respectively, is analyzed. The answer interaction data are as follows:

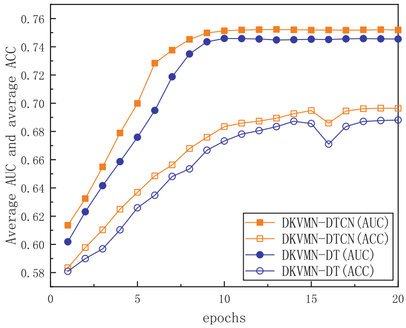

Fig. 5. Comparative experimental results to verify the timing feature processing module.

S1 = [(1,0),(3,1),(1,1),(2,0),(2,1),(3,0)],S2 = [(3,1),(2,1),(3,1),(3,1),(1,0),(2,1)],S3 = [(3,1),(1,0),(2,1),(1,0),(2,1),(1,1)],S4 = [(1,0),(3,1),(1,1),(2,0),(2,1),(3,0)] in the sequence Each item (q_i, r_i) represents one answer record of that student.

By comparing the prediction results of the two models, as shown in Figs. 6 and 7, we can find that the prediction performance of DKVMN-DTCN is better than that of DKVMN-DT. For example, after the completion of the first student's first interaction (1,0), the predicted answer probability of DKVMN-DTCN for the student's next correct answer to knowledge point 1 is 0.24% smaller than that of DKVMN-DT. After analyzing the long-term behavioral characteristics of the student for knowledge point 1, we found that this is because the student always takes a long time to answer the question and requests a prompt when answering knowledge point 1. In summary, DKVMN-DTCN is able to capture the long-term behavioral characteristics of students and has better prediction performance.

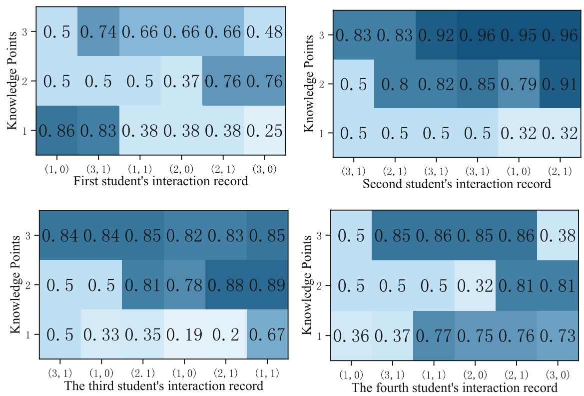

Fig. 6. Visualization of DKVMN-DT Prediction Results.

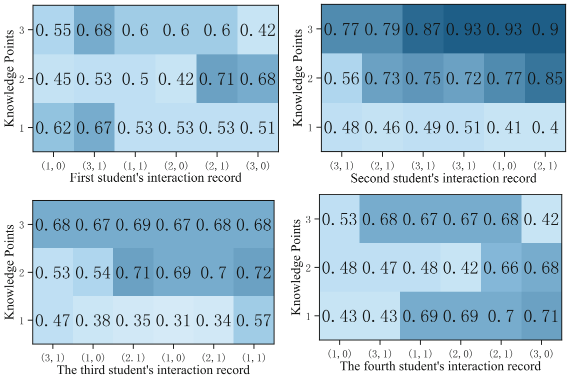

Fig. 7. Visualization of DKVMN-DTCN Prediction Results.

5 Conclusion and Future Work

In this paper, a deep knowledge tracking method based on DKVTMN-DTCN model is proposed for the behavioral characteristics of students with temporal sequences in the learning process and the different effects of different learning abilities on temporal forgetting. The model takes DKVMN-DT as the underlying model, and adds a temporal convolutional network, which is better for handling time-series problems, in the preprocessing process. And considering the influence of answer interval on students' knowledge forgetting under different students' ability, we set the difference between students' wrong answer rate and right answer rate as the a priori learning ability of different students in the writing process of the model, and use it as the basis of students' personalized knowledge forgetting. The experimental results show that the proposed DKVTMN-DTCN model in this paper has better prediction performance and prediction accuracy. It proves the feasibility and effectiveness of our proposed model in the open dataset. In our future work, we will make further research in two directions: on the one hand, integrating user profiles of learners of different ages or domains with knowledge tracking. On the other hand, we will classify and predict students according to their learning ability.

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