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Development of the Foundation of Programming Design Course Based on Cognitive Learning Theory Combined with Project-Based Learning to Enhance Students' Computational Thinking Ability

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Abstract

Background and Aim: Based on relevant policies and literature, such as higher education planning at home and abroad, policies of the Chinese Ministry of Education, educational concepts, cognitive learning theories, project-based learning methods, teaching strategies, and teaching evaluations, researchers interviewed teachers and students on the current foundation of the programming design course. This research and development aimed 1 to study the background information focusing on the course components of the foundation of programming design course to enhance students' computational thinking ability. 2) To develop the foundation of a programming design course based on Cognitive learning theory, combined with Project-based learning to enhance students' computational thinking ability. 3) To determine the effectiveness of implementing the foundation of programming design course based on Cognitive learning theory combined with Project-based learning.

Materials and Methods: The sample of this research was 30 first-year students (1 class) majoring in Network Engineering class 1, in the academic year 2024-2025 of Zhoukou Normal University, Henan Province, China. They are derived from using a cluster random sampling method. The experimental design adopted in this research was a group posttest-only design. The research instruments from each Phase of the study were as follows: Phase I: Interview forms for teachers and students on course-related questions. Phase II: 1) Foundation of programming design course based on Cognitive learning theory combined with Project-Based Learning. 2) 12 lesson plans for the foundation of the programming design course. 3) Evaluation form of computational thinking skills. 4) Learning achievement test. 5)Satisfaction questionnaire. The data were analyzed by using mean, standard deviation, and the one-sample t-test.

Results: The results of this research were as follows: 1) The researcher reviewed the related documents about the Foundation of Programming Design Course and interviewed the 4 teachers and 30 students about problems of the Foundation of Programming Design Course, and the information gathered was used to develop the course. 2) The course development in six aspects: Course principles, Course objectives, Course content, Course instructional strategies, Course media and resources, and Course evaluation. 3) After implementing through Foundation of Programming Design Course based on Cognitive Learning Theory combined with Project-Based Learning, students' computational thinking ability (Knowledge) was higher than the determined criterion of 70% at a significance level of 0.05; students' computational thinking ability (Skills) was higher than the determined criterion of 70% at a significance level of .05. 4) The mean scores of students' satisfaction after implementing the Foundation of Programming Design Course based on Cognitive Learning Theory combined with Project-Based Learning was 4.838 from a possible full mark of 5, and the standard deviation was 0.176, which was statistically higher than the criterion of 70% at the .05 level of statistical significance.

Conclusion: This research confirms the effectiveness of the teaching model based on Cognitive learning theory combined with Project-Based Learning to enhance students' computational thinking ability.

Keywords: Foundation of Programming Design Course; Computational Thinking Ability; Cognitive Learning Theory Combined with Project-based Learning; Course Development

Introduction

In the current era of widespread informatization, the global dependence on informatization continues to deepen, and the continuous adjustment of industrial structure and the deepening of informatization reform

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also affect the development and progress of China's domestic information industry. In this context, the development speed of China's software industry is constantly accelerating. The internationalization of the software industry emphasizes the development of programming talent, requiring students to acquire strong foundational knowledge and diverse coding skills to adapt to global demands. (Aismubiti & Abulitfu, 2016) This requires students in relevant majors to possess solid professional knowledge and practical application abilities. Computer programming, as the most fundamental course in computer science, plays a major role in guiding students to establish computational thinking awareness, master programming skills, and solve real-world problems through the use of computer technology.

At Zhoukou Normal University, the Foundation of Programming Design course serves as a core subject aimed at developing students' logical reasoning, hands-on problem-solving abilities, and creativity. However, current instructional methods face challenges that hinder student engagement and skill development. Traditional teaching approaches struggle to stimulate students' interest, resulting in low classroom efficiency and insufficient hands-on practice. To address these issues, it is essential to reform teaching methodologies and introduce innovative instructional strategies. (Talent Training Program of Zhoukou Normal University, 2022)

Cognitive learning theory highly values students' subjective initiative. Create a situation to elicit the learner's response and provide appropriate reinforcement for each response. (Wang, 2005) Project-based learning is a student-centered teaching method that involves designing and executing projects. (Wang, 2018) Cognitive learning theory combined with Project-Based Learning means teachers are project-oriented, embedding the key and difficult points of the textbook into the project. In classroom teaching and post-class practical training, a teaching method combining Cognitive learning theory with Project-Based Learning is adopted to encourage students to achieve flexible application and operation of programming language and related knowledge and skills. Students can actively participate in programming learning for practical problems, acquire relevant knowledge and skills, and apply them to problem-solving.

Thus, this study aims to develop a Foundation of Programming Design course based on Cognitive Learning Theory and Project-Based Learning to enhance first-year students' computational thinking abilities at Zhoukou Normal University. By adopting this approach, the study seeks to improve programming education by making learning more interactive, engaging, and applicable to real-world challenges.

Objectives

1. To study the background information focusing on the course components of the foundation of the programming design course to enhance students' computational thinking ability.

2. To develop the foundation of a programming design course based on Cognitive learning theory, combined with Project-based learning to enhance students' computational thinking ability.

3. To determine the effectiveness of implementing the foundation of programming design course based on Cognitive learning theory combined with Project-based learning.

3.1 To compare students' computational thinking ability after implementing the foundation of programming design course based on Cognitive learning theory combined with Project-based learning, with a criterion set at 70%.

3.2 To compare the students' satisfaction after implementing the foundation of programming design course based on Cognitive learning theory combined with Project-based learning, with a criterion set at 70%.

Literature review

1. Course development theory

The curriculum refers to a planned, guided learning experience and expected learning outcomes developed under the auspices of a school, through the systematic reconstruction of knowledge and experience, for learners to continuously and willfully improve their social abilities. Demirel (2009) defined

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curriculum development as the dynamic relationship between the objectives, content, learning-teaching process, and evaluation elements of the educational program. (Duran & Mertol, 2020)

For course development, the research suggests developing a course draft based on needs analysis, skills, and abilities, and ensuring that it is suitable for the course platform. In the development stage, research results indicate that curriculum development should focus on student-centered practices, skills, values, and activities. (Kılıç & Saygılı, 2022)

The course development process usually includes six stages: (1) Formulate principles; (2) Determine objectives; (3) Select contents; (4) Determine instructional strategy; (5) Select materials, media, and resources; (6) Determine evaluation methods. Based on the Taylor model and Taba model, the researcher has summarized the teaching model, with the specific steps as follows: (1) Initiation stage: subject matter ; (2) Diagnosis of needs: determine teacher training needs through questionnaire; (3) Formulation of objectives; (4) Organization of content: write program; (5) Selection of learning experiences: experimental design; (6) Organization of learning activities; (7) Project Evaluation: using measurement tools.

2. Cognitive learning theory

Cognitive learning theory is a theory of psychology that defines human behavior by understanding thought processes. It assumes that human beings make choices which sense to them the most. Educators need to propose corresponding teaching strategies for different learning psychological activities in each stage; Pay attention not only to the behavioral changes caused by learning but also to the changes in learners' abilities and attitudes towards learning outcomes. (Lin, 2018)

Cognitive learning theory originated from the representative school of cognitive theory - Gestalt psychology insight theory, which formed in the 1960s. According to Cognitive learning theory, learning rules can be explored by studying people's cognitive processes. There are many viewpoints in Cognitive learning theory, and its core viewpoints mainly include: First, people are the subject of learning, and there are spontaneous learning behaviors; Second, the process of memory, understanding, and problem-solving is the process of human obtaining information; Third, the quality of students' learning depends on their learning effects. Now compare the cognitive learning theories of different schools:

Robert Mills Gagne (1916-2002) believes that "executive control" and "expectation" are two relatively important parts. "Executive control" refers to the influence of internal experience on current learning, and "expectation" refers to the influence of the motivation system on the learning process. According to Gagne's viewpoint, the steps of cognitive learning theory include:(1) Motivation; (2) Understanding; (3) Acquisition; (4) Holding; (5) Recollection; (6) Extraction; (7) Operational; (8) Feedback. in Gagne's view, the complete learning process of learners should be composed of the above eight stages. In each stage of learning, learners' brains will process information to transform information from one form to another. (Gagné, 1985).

David Paul Ausubel (1918-2008) believed that learning should occur through acceptance. This kind of reception requires the learning subject to accept meaningfully, so he proposed the concept of meaningful learning. Effective learning is often a process of gradual differentiation from the most general concepts to specific concepts, which is a complex assimilation process within the learners' psychology. (Seel, 2012)

Jerome Seymour Bruner (1915-2016), a famous American cognitive education psychologist, believes that the purpose of learning is to discover the way of learning and transform the basic structure of the discipline into the cognitive structure in the students' minds. Based on the research on students' cognition and development, he proposed the cognitive structure learning theory, which has been widely discussed by the academic community. Bruner emphasizes the important role of cognitive structure in the learning process and believes that cognitive structure endows experience with regularity and organization so that learners can transcend the existing information and learn from it. (Tomasello, 2016)

According to cognitive education psychologists' views, the researcher has summarized the teaching strategies and steps of cognitive learning theory as follows:

Step 1: The motivation phase refers to the initial stage of the whole learning process. Its main task is to guide the students to have the motivation to learn, that is, the motive of students to achieve their special

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purpose. Therefore, learning motivation is often connected with students' interests. Motivation and learning are combined through the system to achieve their learning goals.

Step 2: Understanding refers to the student's need to pay attention to the external information for the selective stimulation of memory. External information entering the information processing system will be stored in the memory, and this process is selective perception. Selective perception is selected according to its motivations, and it focuses on the aspects of information that are relevant to its motivations.

Step 3: Knowledge acquisition refers to the application of knowledge, consolidation of knowledge, and group discussion. The stored information will enter the long-term memory stage.

Step 4: Analysis and extraction refers to the stage of information retrieval. To enable students to accurately remember and recall learning content, teachers should teach students search methods and strategies. When students retrieve knowledge from short-term memory, but it does not occur in the same context, they can adapt to the new context to extract knowledge and achieve knowledge transfer.

Step 5: The operational phase refers to students' computer operation, programming homework, and practical connections. Teachers should carry out a variety of practice exercises to test whether the students have a real grasp of the learning content. This stage is also known as the reaction generation stage. Through the completion of the job, teachers can promptly and accurately grasp the student's learning level.

Step 6: The feedback phase refers to homework submission and teacher evaluation of student learning outcomes. This stage is very easy for teachers to ignore. After completion of homework, teachers should give timely feedback to enable students to identify whether their work is correct, so that students can know how to further strengthen their learning motivation.

Summary: Cognitive strategies are special and very important skills that are used by learners to guide their attention, learning, memory, and thinking, and run through the cognitive process.

3. Project-based learning

Project-based learning is a student-centered teaching method that involves designing and executing projects. This type of learning can develop knowledge and skills in the cognitive field by promoting exploratory learning and performance, forming teams to solve specific problems, and completing project tasks. The project content comes from real life, and the setting of task goals should have a certain level of height. The project should have a certain level of development, interest, and challenge, and can effectively cultivate students' social and emotional skills during the project learning process. (Wang, 2018)

Professor Gao Zhijun and others from Peking University believe that Project-based learning is a learning process that revolves around a specific learning project, fully selecting and utilizing optimal learning resources, conducting a series of investigations, observations, research, expressing new knowledge, showcasing and sharing learning outcomes, obtaining more complete and specific knowledge through practical experience, internalization and absorption, and exploration and innovation, forming specialized skills and fully developing learning. (Gao &Tao, 2009)

The significance of Project-based learning in supporting this research lies in: (1) Cultivating a spirit of cooperation, and engaging in necessary communication and exchange, to cultivate students' cooperative abilities and social language skills; (2) Cultivating exploratory ability, students solve problems on their own during the process of completing tasks and producing works, and their thinking is trained, which helps to cultivate computational thinking.

The following are the steps of Project-based learning:

Step 1: Preparation refers to instructors providing the scope of the project and the sources of information using identifying them and leading questions in the learning management plan.

Step 2: Topic definition and selection refers to the group of learners jointly finding out topics for the project, studying the possibilities of each topic for selection, and presenting the said topic to the instructors for approval.

Step 3: Collaborative exploration refers to the collaborative exploration stage is the main part of Project-based learning, where students make assumptions and further explore during the completion of project tasks.

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Step 4: Creation and test refer to group members carrying out their tasks and responsibilities as which can be done in synchronous and asynchronous manners according to the convenience of group members. This is accompanied by the instructors' advice. After accomplishing the invention, the workpiece must be tested to measure its effectiveness.

Step 5: Presentation refers to learners summarizing the operation results, preparing a report, and presenting the results of their project to exchange knowledge with other groups.

Step 6: Evaluation and summary refers to teachers summarizing the knowledge learned by students, raising questions to stimulate their thinking, which is beneficial for students to apply the knowledge they have learned to the next project of learning. The evaluation methods are diverse, including teacher evaluation, intra-group evaluation, and inter-group evaluation. Evaluate the process of Project-based learning while evaluating the finished product.

Summary: Project-based learning is a learning management process that encourages learners to take actions and have engagement in learning, ranging from exploration, learning plan, learning design, creation and application of knowledge, and evaluation.

4. Computational thinking ability

Computational thinking ability refers to a series of thinking activities generated by using a series of computer science methods to design and implement problem-solving solutions.

Dong Rongsheng and others believe that, similar to thinking activities such as problem-solving, system design, and human behavior understanding, computational thinking should also be a thinking activity that covers the breadth of computer science. (Chen & Dong, 2013)

Ren Youqun and others believe that computational thinking can help individuals gain a deeper understanding and analysis of complex problems and provide a formal, modular, automated, and systematic solution to specific problems. Therefore, computational thinking is a unique problem-solving process. (Ren et.al, 2016)

In March 2006, Professor Zhou Yizhen, director of the Department of Computer Science at Carnegie Mellon University, published an article titled "Computational Thinking" in the journal Communications of the ACM. In this work, Zhou defines computational thinking as a series of cognitive activities encompassing various aspects of computer science, including problem-solving, system design, and understanding human behavior, all rooted in fundamental computer science concepts. Over time, computational thinking has garnered increasing attention, emerging as a key research focus in both computer science and education. However, despite Zhou Yizhen's contributions to its conceptualization, there is still no clear consensus within the research community regarding its precise definition. (Luo et al., 2021)

Different scholars have put forward different perspectives on the components of computational thinking and classified them. The researcher summarizes the classification and computational thinking ability measured through four components:

1. Problem-solving refers to the thinking process of achieving the goal state from the initial state of a problem. The process of applying various cognitive activities, knowledge, and skills, etc., according to a certain goal, caused by certain program errors, to solving the problem through program operation.

2. System design refers to the process of providing programs to solve specific problems is an important component of computer programming activities. The Foundation of Programming Design course uses the C programming language as a tool for system design.

3. Analysis and organizational problems refer to analyzing the problems encountered in the learning process, identifying the causes of the problems, and summarizing and organizing the problems to find solutions.

4. Systematic solution refers to problems encountered during the programming process, identifying system solutions, inputting correct code, and debugging the program again to ensure accuracy.

Summary: In the Foundation of Programming Design course, students' computational thinking ability is assessed through knowledge (30%) and skills (70%). Knowledge is measured using the Learning

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Achievement Test (LAT), while skills are evaluated through the Computational Thinking Skills Form (CTSF). This research integrates Cognitive Learning Theory and Project-Based Learning to enhance computational thinking by fostering active engagement, problem-solving, and hands-on programming practice, forming the foundation of the proposed instructional model.

Conceptual Framework

In this research, the independent variable was the implementation of the Foundation of Programming Design course based on Cognitive learning theory combined with Project-based learning, and the dependent variables were students' computational thinking ability and students' satisfaction.

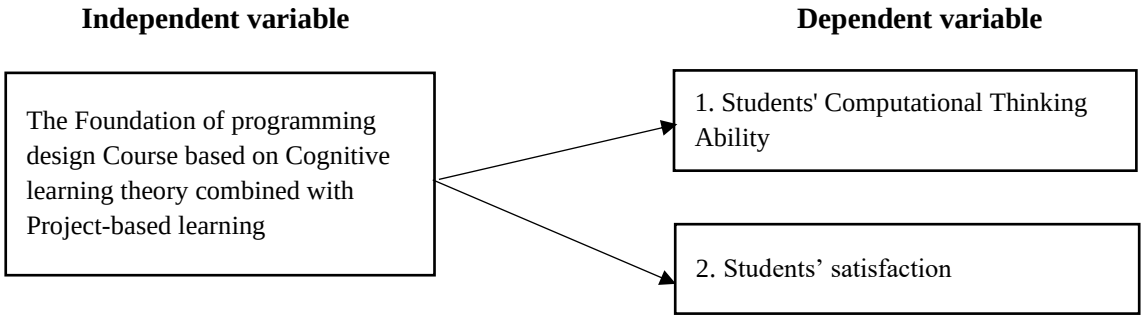

Figure 1 The figure of the Research Conceptual Framework

Methodology

Phase 1: Study the background information, focusing on the current course components of the Foundation of Programming Design course and existing problems

Study related literature on the Foundation of Programming Design course and interview the teachers and students of related majors of Zhoukou Normal University.

1. Target group

1) 5 teachers were teaching the Foundation of Programming Design at the School of Artificial Intelligence at Zhoukou Normal University. In this research, 4 teachers were selected by purposive sampling.

2) 120 students have learned the Foundation of Programming Design course. In this research, 30 students were selected by purposive sampling.

2. Research instrument

1) Interview form for teachers teaching the same subject about course components and the problems existing in the Foundation of a programming design course, and the interview form mainly includes 4 aspects: 1) Teaching objectives, 2) Teaching contents, 3) Teaching methods, and 4) Evaluation.

2) Interview form for students about course components and the problems existing in the Foundation of Programming Design course. The interview form mainly includes 3 aspects: 1) Instructional strategies, 2) Media and resources, and 3) Evaluation.

3. Data analysis

1) The data on existing problems is collected by the interviewing process and the voice record tool.

2) Content analysis is used for analyzing and summarizing collected data.

Phase 2: Developing the Foundation of Programming Design Course based on Cognitive learning theory, combined with Project-Based Learning, to enhance students' computational thinking ability

The purpose of this phase was to design the draft course document and determine the quality of the draft course document before its implementation.

1. Developing a Foundation of programming design course based on Cognitive learning theory combined with Project-Based Learning. This step aimed to develop the draft course according to the results from the first phase. The components of the draft course consisted of: 1) Formulate principles of the course; 2) Determine objectives of the course; 3) Select course content; 4) Determine instructional strategy/process; 5) Select/develop media and resources; 6) Determine evaluation methods.

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2. Determining the quality of developing a Foundation of programming design course based on Cognitive learning theory combined with Project-Based Learning. This step aimed to determine the quality of the draft course document before its implementation. The draft course document was evaluated by five experts regarding the appropriateness and consistency of each component of the draft course. Firstly, an appropriateness evaluation involves the appropriateness of each component of the draft course document, including 1) the principles of the course, 2) the objectives of the course, 3) the course contents, 4) instructional strategies, 5) media resources, and 6) course evaluation. Secondly, consistency evaluation involves the internal consistency among the components of the draft course document. Experts' recommendations were used to revise the course document.

3. Constructing 12 lesson plans, considering the overall structure and format of each lesson; Constructing and examining the quality of the Learning Achievement test; Constructing and examining the Computational Thinking Skills Form (CTSF); Constructing and examining the quality of the Questionnaire for students' satisfaction.

1. Target group

Five experts who evaluated the draft course consisted of 2 specialists in the course field, 2 specialists in instruction relevant to computational thinking, and 1 specialist in the measurement and evaluation field.

2. Research instrument

The instrument used for evaluating the draft course document was the appropriateness and consistency evaluation form.

3. Data analysis

The researcher offered the course evaluation form to a group of experts to examine or evaluate the draft course document. After gathering the data, the collected data were analyzed for the appropriateness and consistency of the course document.

Phase 3: Determine the effectiveness of implementing the Foundation of Programming Design course based on Cognitive learning theory, combined with Project-Based Learning, to enhance students' computational thinking ability

1. Population and sample

The population in this research was 150 undergraduate students (5 classes) from the major in Network Engineering from the School of Artificial Intelligence, Zhoukou Normal University, Henan Province, China.

The sample of this research was 30 undergraduate students (1 class) majoring in network engineering from the School of Artificial Intelligence, Zhoukou Normal University, Henan Province, China. They are derived from using a cluster random sampling method.

2. Research Instruments

Instruments for data collection consisted of three parts.

2.1 Learning Achievement Test: The test includes 30 multiple-choice questions about the mastery of the Foundation of Programming Design course, covering the knowledge learned in the course. Analyzing each item to find out the item difficulty (p) and item discrimination (r), including reliability. Item difficulty (p) should range from 0.20-0.80, and item discrimination (r) should be more than 0.20. The reliability of the test is computed using the formula of Kuder and Richardson formulas 20 and should be more than 0.7 (Richardson & Kuder, 1939). The test had difficulty (p) between 0.40-0.80, item discrimination (r) between 0.38-0.75, and KR20 equal 0.72, which means the test can be used.

2.2 Computational Thinking Skills Form (CTSF): The Skills are evaluated by the Computational Thinking Skills Form (CTSF), which consists of 4 aspects: (1) Problem-solving, (2) System design, (3) Analysis and organizational problems, (4) Systematic solution. Analyzing each topic of the Computational Thinking Skills Form to find out the inter-rater reliability by using two specialists to mark the scores of 30 students after calculating the value of the scores to get inter-rater reliability for rubric assessment (Reddy & Andrade, 2010) using Pearson correlation coefficient formula was equal 0.925 that mean the reliability coefficient value was very high. So, the Computational Thinking Skills Form was appropriate for collecting data.

2.3 Questionnaire for students' satisfaction: The main purpose of this questionnaire is to explore the impact of the foundation of programming design courses based on Cognitive learning theory and Project-based learning on students' computational thinking abilities. This questionnaire consists of 20 questions, covering your satisfaction feedback on learning the basic course of programming based on

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Cognitive learning theory combined with Project-based learning. The results of experts evaluated the Criteria for assessing the Satisfaction Questionnaire result, the mean scores from 4.00 to 4.60, the standard deviation from 0.45 to 0.89, and the appropriateness and consistency high level. Trying out the students' satisfaction questionnaire, then each item of the questionnaire was calculated to find out the reliability. The reliability of the questionnaire was computed using Cronbach's Alpha formula, Coefficient for Reliability and should be more than 0.7. The questionnaire had a reliability index of 0.83, which means the questionnaire can be used.

Relying on research results for data collection to determine the effectiveness of implementing the Foundation of Programming Design course based on Cognitive learning theory, combined with Project-Based Learning, to enhance students' computational thinking ability.

3. Data collection

The course was implemented in the samples in the first semester of the 2024-2025 academic year. The procedures of data collection during the course implementation process were as follows:

3.1 The samples that were assigned to the experimental group were taught using instruction through the developed Foundation of Programming Design Course. This group was taught through 12 lesson plans, and the allocation time for instruction was two months.

During instruction through the course implementation process, the researcher observed and recorded data, including the teaching process, the learning process, classroom atmosphere, students' behavior, teacher's behavior that occurred in the classroom.

3.2 After finishing the instruction, the samples received the posttest by using the instruments.

3.3 The samples are given the students' satisfaction questionnaire to express their opinion toward the course.

4. Data analysis

In this research, quantitative data were analyzed using the statistical program in line with the research objectives.

4.1 Statistics used to determine the different significance at the .05 level of scores on Students' Computational Thinking Ability after learning through the Foundation of Programming Design Course by using a one-sample t-test.

4.2 Statistics used to assess the students' satisfaction with the Foundation of the programming design Course by using the arithmetic mean, standard deviation, and one-sample t-test to compare students' satisfaction with the criterion of 70%.

Results

Phase 1: The findings of the study, the background information focusing on current course components of the Foundation of Programming Design course, existing problems, and interviews with teachers and students relevant to the problems of the current

The purpose of this phase was to investigate and review the relevant literature about current course components of Foundation of programming design course components and existing problems:1) background information focusing course components 2) Cognitive learning theory 3) Project-based learning 4) computational thinking ability 5) existing problems as well as study the related research such as the relevant documents and current situation. The findings of this phase, which were used in designing a course, were presented as follows:

1. The findings of studying the relevant documents on the Foundation of the Programming Design course

Summarize the process and successful experience of relevant literature cases. Through an in-depth understanding of relevant teaching strategies, teaching effectiveness, and project cases, a solid theoretical and practical foundation has been laid for the construction of effective teaching strategies in the future.

2. The findings of interviewing the teachers and students of the Foundation of Programming Design course at Zhoukou Normal University

The researcher applied course development content to teaching, conducted research on different teaching methods, collected data from four other teachers in the same subject, and ultimately formed a new curriculum system for the "Foundation of Programming Design" course based on cognitive learning theory and project-based learning, to improve students' computational thinking ability. Based on the above course problems, solutions were proposed, and corresponding teaching plans were formulated.

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Phase 2: The finding of development of the Foundation of programming design course based on Cognitive learning theory, combined with Project-Based Learning to enhance computational thinking ability and satisfaction of students

1. The findings of the course development

The draft course document consists of six components:

1) Rationale of the course

The foundation of programming design is a discipline that implements specific program operations and emphasizes applications. The programming foundation of the new curriculum must be applied to students' daily professional learning; The computer skills operation in this course should achieve strong practicality and applicability, and be able to expand students' professional knowledge to adapt to the application of software engineering in modern society; Cultivate students' basic methods and ideas for programming to meet the national requirements for applied talents. The teaching strategy of the course "Foundation of Programming Design" is based on the learning philosophy of "Cognitive learning theory combined with Project-Based Learning". This requires students to accumulate learning and acquire self-development, motivation, creativity, positive thinking, and practical application abilities in their studies. Develop knowledge and skills in cognitive and project-based learning domains, solve specific problems, and complete exploratory project tasks.

2) Aim of the course

Knowledge: Students can initially possess the ability to transform practical problems into computer language computational models.

Process/Skill: By mastering the basic ideas, processes, and methods of programming and software development, students can apply them to practical problems and choose appropriate programming solutions according to their needs.

Attitude: Students can discover, analyze, design, and solve problems, as well as have the ability to continuously learn and adapt to social development.

3) Course content

This research includes 12 lesson plans, content, and 5 chapters of teaching activities. This research focuses on cultivating and improving students' abilities in problem-solving, system design, analysis, and organizational problems, and systematic solutions. Students can understand programming knowledge related to theories and projects, Logical thinking ability, object-oriented programming skills, and knowledge of programming design. Knowledge to write a program with a clear structure and good readability in the C language, and will test cases to complete program testing.

4) Instructional process

In the foundation of the programming design course, learning and teaching activities are not limited to traditional learning methods. By using the constructed Cognitive learning theory combined with Project-Based Learning methods, students can obtain richer learning outcomes. The brief steps are as follows:

Step 1: Preparation and initiation refers to the teacher and students providing the scope of the project and the sources of information using identifying them and leading questions in the learning management plan.

Step 2: Determine the topic refers to the group of students jointly finding out topics for the project, studying the possibilities of each topic for selection, and presenting the said topic to the teacher for approval.

Step 3: Collaborative exploration refers to emphasizing student-centered teaching, actively leveraging their subjective initiative and exploratory spirit, and creating a relaxed and enjoyable classroom learning environment for students.

Step 4: Knowledge acquisition refers to the application of knowledge, consolidation of knowledge, and group discussion. The stored information will enter the long-term memory stage.

Step 5: Operation and presentation refers to students' computer operation, programming homework, and practical connection. Teachers should carry out a variety of practice exercises to test whether the students have a real grasp of the learning content. This stage is also known as the reaction generation stage. Through the completion of the job, teachers can promptly and accurately grasp the students' learning level.

Step 6: Feedback and evaluation refer to teachers summarizing the knowledge learned by students, raising questions to stimulate their thinking, which is beneficial for students to apply the knowledge they

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have learned to the next project of learning. The evaluation methods are diverse, including teacher evaluation, intra-group evaluation, and inter-group evaluation.

5) Instructional material

The teaching media and resources include textbooks, lesson plans, multimedia resources, PPT courseware, learning task lists, experimental reports, and learning tools: learning communication software, OJ problem-solving system, and Dev C++compilation environment.

6) Learning assessment

The information collected through learning assessment can help determine students' performance. These pieces of information also help guide the course and teaching methods to meet the needs of students. The form of evaluation is determined to be consistent with the objectives, content, and teaching and learning process. The assessment in the new course includes: 1. Students' learning achievement test; 2. Students' computational thinking skill form; 3. Student satisfaction questionnaire.

2. The findings of the course document evaluation by experts

This step aimed to assess the quality of the draft course document before its implementation. Experts evaluated the appropriateness and consistency of each component of the draft curriculum. The results indicated that the experts rated the overall course development at a high level, with a mean score of 4.49 and a standard deviation of 0.60. These findings are statistically significant, confirming the suitability of the draft curriculum for implementation.

Phase 3: The findings determine the effectiveness of implementing the Foundation of Programming Design course based on Cognitive learning theory, combined with Project-Based Learning, to enhance students' computational thinking ability.

The finding of a comparison of students' computational thinking ability after learning through the foundation of programming design course based on Cognitive learning theory, combined with Project-based learning.

Table 1 The Findings of comparing students' computational thinking ability (Knowledge) after implementing through the foundation of programming design course based on Cognitive learning theory combined with Project-based learning, with a criterion set at 70%

Group	n	Full score	Criteria score	Mean	*SD*	*t*	*p*
Experimental group	30	30	21	23.70	2.902	5.095**	0.000

** $p<0.01$

As presented in Table 1, after implementing the foundation of a programming design course based on Cognitive learning theory combined with Project-based learning, the students' computational thinking ability (Knowledge) was higher than the determined criterion of 70% at a significance level of .05 (M = 23.70 out of 30, SD = 2.902, t = 5.095, p = 0.000).

Table 2 The Findings comparing students' computational thinking ability (Skills) after implementing through the foundation of programming design course based on Cognitive learning theory combined with Project-based learning, with a criterion set at 70%

Group	n	Full score	Criteria score	Mean	*SD*	*t*	*p*
Experimental group	30	70	49	67.97	2.606	19.931**	0.000

** $p<0.01$

As presented in Table 2, after implementing through foundation of programming design course based on Cognitive learning theory combined with Project-based learning, the students' computational thinking ability (Skills) was higher than the determined criterion of 70% at a significance level of .05 (M = 67.97 out of 70, SD = 2.606, t = 19.931, p = 0.000).

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Table 3 The findings of comparing the students' satisfaction after implementing the foundation of programming design course based on Cognitive learning theory combined with Project-based learning, with the criterion set at 70%

Group	n	Full score	Criteria score	Mean	*SD*	*t*	*p*
Experimental group	30	5	3.51	4.838	0.176	41.336**	0.000

** $p<0.01$

As presented in Table 3, the mean scores of students' satisfaction after implementing the foundation of programming design course based on Cognitive learning theory combined with Project-based learning was 4.838 from a possible full mark of 5 and the standard deviation was 0.176 which was statistically higher than the criterion of 70% at .05 level of statistical significance (t = 41.336, p = .000).

Discussion

This research aims to 1) study the background information focusing on course components of the foundation of programming design course to enhance students' computational thinking ability, 2) develop the foundation of programming design course based on Cognitive learning theory combined with Project-based learning to enhance students' computational thinking ability, 3) determine the effectiveness of implementing the foundation of programming design course based on Cognitive learning theory combined with Project-based learning, 4) compare students' computational thinking ability after implementing through foundation of programming design course based on Cognitive learning theory combined with Project-based learning with criterion set at 70%, 5) compare the students' satisfaction after implementing through the foundation of programming design course based on Cognitive learning theory combined with Project-based learning with the criterion set at 70%.

C language is a foundational procedural programming language, yet students often struggle to integrate theoretical knowledge due to insufficient hands-on practice. While the syntax itself is not highly complex, learners frequently find it challenging to establish connections between different programming concepts. For instance, understanding the interplay between *if* and *while* statements or selecting appropriate loop conditions in *while* and *for* loops is difficult to grasp through theoretical instruction alone. (Lu, 2015) Moreover, many educators tend to focus on theoretical teaching without adequately incorporating practical exercises, which limits students' ability to apply programming concepts effectively. (Shen, 2023)

To address these challenges and enhance students' learning outcomes in *C Language Programming*, innovative teaching strategies should be implemented to promote flexibility in learning objectives, allowing students to tailor their learning experiences to their individual needs. (Shen, 2023) The *Foundation of Programming Design (C Language)* course is an essential introductory course for first-year undergraduate students majoring in computer science. While these students typically begin with no prior programming experience, they exhibit high levels of enthusiasm, cooperation, and adaptability, making this stage ideal for fostering computational thinking skills. (Yuan, 2023)

A comprehensive instructional framework that integrates Cognitive Learning Theory and Project-Based Learning (PBL) can effectively enhance students' abilities in system design, problem analysis, organizational thinking, and systematic problem-solving. By engaging in *discovery-based learning*, students are encouraged to explore programming concepts actively, fostering skills such as information collection and processing, independent knowledge acquisition, critical thinking, and collaborative problem-solving. (Wang, 2014)

Additionally, integrating modern educational technology and implementing a "descriptive algorithm" teaching model can further support the development of computational thinking skills. (Wan, 2023) This approach enhances students' motivation, making their learning experience more meaningful and effective. (Wang, 2021) To validate the effectiveness of this model, the research incorporates evaluations of course structure, lesson plans, computational thinking competencies, and student satisfaction through expert assessments. Since these evaluation criteria fall within the effective range, this study provides a solid foundation for project-based research in programming education.

The development of computational thinking in programming education involves both knowledge acquisition and skills development. Knowledge is cultivated through computational tools that enhance problem-solving, while skills such as modeling, heuristic reasoning, and focus separation are critical for effective programming (Dong, 2018). Computational thinking consists of four core components—problem-

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solving, system design, problem analysis, and systematic solutions—which closely align with the programming design process (Liu et al., 2017).

Traditional programming instruction often emphasizes problem-solving results over cognitive processes, leading students to focus on technical execution rather than conceptual understanding. Integrating Cognitive Learning Theory with PBL shifts instruction toward a process-oriented approach, fostering higher-order thinking skills. Research suggests that students engaged in PBL-based programming courses demonstrate improved problem-solving abilities, logical reasoning, and adaptability in both academic and real-world contexts (Liu et al., 2017).

Beyond programming, computational thinking supports critical thinking, analytical reasoning, and interdisciplinary problem-solving. Moreover, enhancing computational thinking strengthens educators' instructional strategies, teaching confidence, and professional development, creating a reciprocal cycle of improvement that enhances student learning outcomes.

Conclusion

This research confirms the effectiveness of the teaching model based on Cognitive learning theory combined with Project-Based Learning to enhance students' computational thinking ability. The enhancement of performance through theoretical tests and practical projects confirms that this research can effectively combine theoretical knowledge and practical operations to enhance students' computational thinking knowledge and skills.

Future research can further explore the impact of Cognitive learning theory combined with Project-Based Learning on students' learning outcomes and professional abilities, as well as the applicability of the method in other disciplines and environments. We should also consider how to utilize online technology tools and platforms to further enhance the interactivity and practicality of teaching. By continuously improving teaching strategies and tools, we can better prepare students for the rapidly developing field of software engineering and enable them to succeed in their professional technical fields after graduation. This not only helps to improve the quality of education but also provides a solid foundation for cultivating professional and technical talents in higher education.

Recommendation

Recommendation for implication

1) In the integration of Cognitive learning theory combined with Project-Based Learning, there are six steps, and the third collaborative exploration step is the most important because students' learning initiative and computational thinking ability are well reflected in this step.

2) For teachers, rich teaching resources are more conducive to the development of courses, abandoning the traditional approach of focusing on grammar and introducing language rules in isolation. Teachers discuss programming language processing project issues with students from an application perspective. Students participate in the design and development process of the entire project, learning by doing and practicing by learning.

3) Students are willing to accept new teaching methods and believe that they can enhance their interest and enthusiasm for learning programming through communication and interaction. From a practical perspective, it can provide students with a richer learning experience.

4) The Cognitive learning theory combined with the Project-Based learning teaching method not only helps students improve their computational thinking ability, but also indirectly stimulates their learning spirit of active exploration and research, gradually helping them develop good study habits and qualities in their studies.

Recommendation for further research

1) Further investigate existing literature on cognitive learning and project-based learning. Integrate these methods into instructional design, and investigate the impact of teaching on student learning outcomes. Only by building a solid theoretical framework can new teaching methods be successfully implemented.

2) The teaching methods based on cognitive learning theory, which combine project-based learning, should be closely integrated with key concepts and skills in programming applications. Deepen theoretical research in future teaching to provide detailed content for evaluating computational thinking. Guide standardizing evaluation criteria.

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3) Integrating the content system of computational thinking into teaching practice and cultivating students' ability to analyze and solve problems needs to be gradually promoted in universities. Therefore, developing new evaluation models and quantifying evaluation systems are the next steps that need to be explored in teaching reform.

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