

Research on Game-based Teaching Design and Application Based on Computational Thinking

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Abstract: In the current age of swift advancements in information technology, the significance of computational thinking has become increasingly pronounced. The challenge of educators is how to effectively cultivate students' computational thinking skills. In the context of digital transformation in education, this study emphasizes that teacher trainees should pay attention to and explore how to foster students' computational thinking. Drawing on theories related to "computational thinking" and "gamified teaching," the research proposes a gamified teaching design framework aimed at developing computational thinking, and accordingly designs classroom teaching activities. Through practical teaching verification, it is found that gamified teaching can effectively enhance students' computational thinking abilities, providing teacher trainees with a novel teaching strategy for better nurturing students' computational thinking. This study highlights the importance of integrating gamified teaching methods into the curriculum to promote computational thinking skills among students. By implementing these strategies, teacher trainees can better prepare their students for success in the digital age.

Keywords: Computational Thinking; Game-based Teaching; Information Technology; Instructional Design; Application Research

1. Introduction

Computational thinking is one of the three major scientific thinking skills that learners in the 21st century must master. In response to the challenges of educational reform and to

secure a strategic advantage in future education, countries around the world have incorporated the cultivation of computational thinking into their directions for educational reform, aiming to meet the needs of societal development and human advancement in the information age. As students specializing in educational technology, we will soon enter a curriculum where the subject of Information Technology has been renamed Information Science and Technology in the 2022 compulsory education curriculum plan. This change reflects the academic community's deeper understanding and research on the subject. Compared to Information Technology, Information Science and Technology places equal emphasis on science and technology, better serving the goals of core competency development. The starting point of the Information Science and Technology curriculum is to cultivate disciplinary core competencies, and it is imperative to develop computational thinking ability as one of the basic core competencies within the elementary Information Science and Technology curriculum. Although computational thinking was identified as one of the four core competencies quite early on, many teachers struggle to grasp the essence of computational thinking and are unable to effectively develop this skill in students. Gamified teaching is a breakthrough that makes abstract computational thinking accessible and easy to understand. Based on an analysis of elementary students' learning situations, gamified teaching can stimulate students' interest in autonomous learning. By employing gamified teaching methods and integrating educational objectives into game activities, teachers can not only energize the classroom and foster students' creativity but also allow

students to subtly develop computational thinking while they "play."

2. Literature Review

As for the research of computational thinking, Pan et al. put forward a strategy map for the cultivation of decomposed thinking, and carried out classroom case design and practical exploration[1]. Taking "Nine creative Spaces" as an example, Liang proposed four ways to cultivate junior high school students' computational thinking from the perspective of maker education[2]. Liu designed a framework of interdisciplinary teaching activities to cultivate primary school students' computational thinking[3]. Through the above literature analysis, it can be seen that the current domestic research on the way to cultivate computational thinking mostly focuses on programming, which is relatively simple and needs further research. Shang et al. systematically sorted out the research history of traditional games and electronic games, and hoped to return to the essence of education by reshaping learning methods in the future[4]. Li et al. constructed an unplugged computer science gamification teaching model, which consists of seven steps: "selecting topics, marking computational thinking, designing games, organizing games, thinking guidance, summarizing models, and transfer and application", and cultivated computational thinking[5] through this teaching model; Based on the elements of computational thinking, Wang and Yue et al. proposed the game-based teaching model[6,7].

The research of computational thinking and gamification teaching in foreign countries precedes that in China. In 2012, the Media Lab of Massachusetts Institute of Technology (MIT) proposed a three-dimensional framework of computational thinking, which includes computational concept, computational practice and computational concept, and triggered the research and evaluation of computational thinking at the practical level[8]. Kazimoglu et al. combined computational thinking ability with program structure design in game task design, allowing students to design algorithmic solutions through programming and symbolic representation and complete tasks[9]. Based on experiential learning theory, immersion theory and game design theory, Kiili proposed an experiential game model combining

educational theory and game design[10]. Elshiekh et al. conducted an empirical study on the use of learning gamification in the curriculum and found that badges can encourage students to actively participate in the curriculum, which is a very effective learning stimulus[11]. Bell and two primary and secondary school teachers in New Zealand wrote Computer Science Unplugged based on their own teaching experience, detailing how to cultivate students' computational thinking in gamification teaching[12].

Through the above literature analysis, it can be seen that taking game-based teaching as a new educational means and cultivating students' computational thinking ability through gamification and game education is the focus of educators, which is worthy of further consideration and exploration.

3. Game-Based Instructional Design Framework for Cultivating Computational Thinking

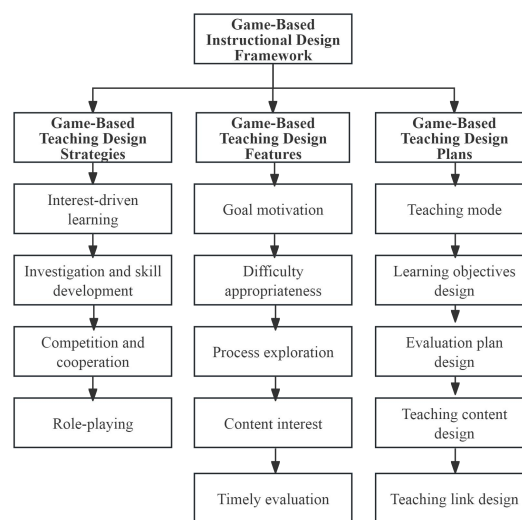


Figure 1. Game-Based Instructional Design Framework for Cultivating Computational Thinking

The core idea of teaching design in this study is to use game-based teaching to cultivate students' computational thinking ability, help students get better stage experience and cultivate the thinking of breaking big problems into small ones step by step to solve them, so as to form a virtuous circle of active inquiry — problem solving — achievement — re-exploration, which is consistent with the inquiry skills in game-based teaching strategies. To sum up, the instructional design framework

of this study is based on the four-step implementation process of the game-based teaching mode, and the instructional design framework including the game-based instructional design strategies, design features and design schemes is designed, as shown in Figure 1.

4. Game-based Teaching Practice for Cultivating Computational Thinking

4.1 Teaching Object

The objects of this study are grade 4 students in a primary school in Xiangyang City, Hubei Province. According to the quasi-experimental research method, two existing classes of Grade 4 class 1 and Grade 4 class 3 are selected as the investigation objects of the experimental class and the control class, and the diagnostic evaluation is carried out before the curriculum experiment. The overall learning ability of the students in the two classes is relatively balanced, almost normal distribution. Therefore, it is sufficient to conduct a controlled experiment in these two classes.

4.2 Teaching Content

The content of "Magic Coding 1" is selected from the first unit of the information technology textbook in the second volume of the fourth grade of Electronic Industry Publishing House. The teaching content mainly includes: looking for coding in life, understanding the role of coding and exploring the secret of coding. It mainly allows students to explore coding in life through group cooperation, understand the meaning of coding and the information contained in coding, and complete the learning of coding through the creation of a series of situations such as helping police officers solve crimes and the selection game for trainee police officers. Through the study of this course, students will have a preliminary understanding of coding.

4.3 Teaching Implementation

Based on the game-based teaching design framework of computational thinking training proposed in this paper and the cognitive thinking characteristics of primary school students, a game-based teaching case based on computational thinking is designed. The specific implementation process is shown in Table 1.

5. Experiment Implementation and Results

In this study, 40 students from class 401 and 42 students from class 403 participated in the experiment, and the pre-test and post-test recovered 82 samples, with a recovery rate of 100%.

In this study, SPSS28.0 was used to conduct independent sample t test on the pre-test data of the experimental group and the control group. The statistical data are shown in Table 2. As can be seen from the table, the average value of pre-test in experimental class and control class is 10.07, and the average value of pre-test in control class is 10.43, with a significance of $0.544 > 0.05$. The data indicate that there is no difference in the initial computational thinking level of the two classes, that is, the overall level of pre-test computational thinking in the two classes is equal.

In this study, SPSS28.0 was used to conduct paired sample t test on the pre and post test data of the experimental group. The analysis results are shown in Table 3 below. As can be seen from the table, the average value of pre-test was 10.43, and the average value of post-test was 14.33, with a significance $< .001$. The data indicated that the experimental class showed a difference in the level of computational thinking after the game-based teaching, that is, the game-based teaching greatly improved the level of computational thinking of the experimental class.

In this study, SPSS28.0 was used to conduct independent sample t test on the pre-test and post-test data of the experimental group. The analysis results are shown in Table 4 below. As can be seen from the table, the average value of pre-test was 10.43, and that of post-test was 14.33; The average value of the pre-test and post-test of the control class is 10.07 and 10.43. The significance of the post-test is $< .001$. It can be seen from the data that although the traditional teaching mode can also improve the level of students' computational thinking, the game-based teaching mode can improve students' computational thinking ability more quickly and effectively than the traditional teaching.

Based on the experimental results, it can be found that the game teaching mode can effectively promote the training of primary school students' computational thinking. In the

study, it is found that teachers need to spend more time and energy to complete the project teaching design. Schools can provide more and better learning platforms to meet the needs of students' self-study and teachers' teaching. Educators can make more educational games, which are convenient for teachers and students to use. Teachers continue to delve into game-based instructional design based on students'

physical and mental development, so that games can promote education. This experiment has been carried out for a short time, and there are still some areas that need to be improved in the design and implementation of the experiment. The experimental samples are limited, and it is necessary to further expand the number of samples to verify its effect.

Table 1. The Implementation Process of the Game Teaching Case Based on Computational Thinking

Course name: "Magic Coding 1" Lesson time: the first lesson			
Teaching Sessions	Content of class activities	Design intent	Student performance
Situation Lead-in	Context creation: Import through identity guessing games. We are born with a personal ID number, this ID number will not change with our residence, school, growing up, each part, each car also has a special number, these numbers are actually coding. In this lesson, let's learn about these magic codes through the ID number!	Use interactive games to stimulate students' enthusiasm for learning and introduce the topic of this lesson.	The students showed high enthusiasm for the game process in which both the teacher and the students participated.
Put Forward Missions	Activity 1. Exploring Coding in Your Life (5 minutes) Play Video "Coding in Life" 1. What are the codes in your life? 2. Do codes consist only of numbers? Why? 3. Why use coding? Students work in small groups to explore and answer questions.	By exploring the coding in life, students can improve their application ability in real life.	When watching the video, the students showed an active discussion on the questions raised. In group cooperation, the students also verified the answers through the Internet search engine to ensure the correctness of the discussion answers.
Game exploration and group cooperation	Activity 2. Help find suspects Play NEWS: Esplanade Evening News - The Jewel Heist Create the situation: there was a major jewelry robbery in Binhai, and the police found the following four clues at the scene:  Clue 1: Incomplete ID number: x5xxxx198xx9xx1236 Clue 2: The suspect should be an adult male Clue 3: The suspect has a local accent Clue 4: The bank card information used by the suspect: 6665430571258064 Task 1: Information contained in the ID card number (7 minutes) Students work in small groups to explore the information contained in the ID card number	Through the discussion of the bank card information, to understand the bank card code information, and then complete the learning task in two stages, is an application of the ID card code, can improve students' ability to solve problems.	Students show great enthusiasm for the form of crime solving, and can actively explore the information contained in the ID card for reasoning and judgment. In the process of demonstration and communication, the classroom atmosphere was very active and confident.
Communication Display	Students communicate the information contained in their ID number		
Expansion Promote	Task 2: Helping Officers Identify Suspects (5 minutes) Students use the rules of the ID number and the information given by the teacher to find the information contained in the bank card number and help the police officer solve the case.	Cultivate students' ability of thinking transfer	Students actively participate in discussions and look for clues that contain information

Summary Evaluation	Create a game situation: In the students want to choose two trainee police detectives, through the game "trainee police detective" to run the game. Teachers give timely evaluations of classroom performance.	Knowledge is consolidated through games	Students actively participate in the game and seriously discuss the correct answers
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Table 2. The Difference in Pre-test between Experimental Class and Control Class

Groups	Mean	T	Saliency
401 (Control class)	10.07	6.10	0.544
402 (Experimental class)	10.43		

Table 3. The Differences in Pre-test and Post-test of Experimental Class

Groups	Mean	T	Saliency
Pre-test	10.43	5.320	<. 001
Post-test	14.33		

Table 4. The Difference between Experimental Class and Control Class

Classes	Mean	T	Saliency
Pre-test	401 10.07	6.10	0.544
	403 10.43	6.11	0.543
Post-test	401 10.85	4.579	<. 001
	403 14.33	4.622	<. 001

6. Conclusion

In recent years, computational thinking has attracted more and more attention. Many experts suggest to cultivate computational thinking from childhood. In primary school, students should rely on information technology courses and related interest classes to cultivate computational thinking. This study puts forward a game-based teaching framework for cultivating primary school students' computational thinking. Experimental cases are compiled and implemented. The experimental results show that game-based teaching can stimulate students' interest in learning and make students think actively, which can effectively promote the cultivation of primary school students' computational thinking. At the same time, the game-based teaching mode of cultivating primary school students' computational thinking also puts forward new ideas for the research of teaching mode, and also provides empirical support for the theoretical research of teaching mode.

Acknowledgments

This work was supported by The Teaching Reform Research Project of Hubei University of Education (No. X2023001), The Research project of Philosophy and Social Science of Education Department of

Hubei Province (No. 22Q211), and Scientific Research Foundation of Hubei University of Education for Talent Introduction (No. ESRC20220045).

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