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Research on Scaffolding Teaching Design of Scratch for the Cultivation of Computational Thinking in Primary School

-- Taking the Game Design of Penguin Skiing as An Example

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Abstract

Nowadays, computational thinking is considered to be the thinking ability that information talents must possess in the 21st century. This paper discusses how to improve the effect of Scratch programming teaching and cultivate learners' computational thinking based on the scaffolding teaching theory, thus proposing a Scratch scaffolding teaching model for the cultivation of computational thinking. Taking the game programming of "Penguin Skiing" as an example, the teacher creates learning situation by introducing an example, helps students break down tasks and adopts multiple evaluation methods, allowing students to learn in the process of exploration. In this way, students will be driven by interest and evaluation to learn, and driven by problems to think. The teaching effect of Scratch programming will be improved, and the learners' computational thinking ability will be cultivated.

Keywords

Scaffolding teaching; Scratch; Computational thinking.

1. Introduction

Nowadays, the rapid development of information technology makes the demand for information talents in the new era becomes very urgent. As early as 2000, the "Information Technology Curriculum Guideline for Primary and Secondary Schools (for trial implementation)" pointed out that "students should cultivate good information literacy and use information technology as a means to support lifelong learning and cooperative learning". Computational thinking is the core content of information literacy. The integration of computational thinking into the information technology curriculum in primary and secondary school is of great value in enhancing the "thinking" and "basic" characteristics of the information technology curriculum [1].

However, programming languages such as C++, Python and Java are so complex and abstract in structure that is not suitable for primary school students. Scratch is an open-source program with fun, easy-to-use and visual features that can stimulate learners' interest in programming and create a psychological need for coding. The scaffolding approach emphasizes decomposing tasks and providing clues to help learners build a conceptual framework, which enables learners to master coding knowledge, develop computational thinking, and promote cognitive development in the process of programming.

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2. Definition of concepts

2.1. Computational Thinking

In 2006, Professor Yi-Zhen Zhou first proposed the concept of Computational Thinking in the Journal of the Association for Computing Machinery (ACM), which is a series of thinking tools that cover the breadth of computer science by using basic computer science concepts to solve problem, design systems and understand human behavior [2]. In 2013. Dr. Cynthia Selby and Dr. John Woollard from the University of Southampton proposed that computational thinking included five aspects of algorithmic thinking, evaluation, decomposition, abstraction, and generalization [3]. In 2017, China's "Information Technology Standards for General High Schools (for trial)" pointed out that computational thinking is an approach that uses ideas from the field of computer science to define problems, abstract features, build structural models, organize data reasonably and form solutions [4]. Computational thinking is not rigid procedural thinking, nor is it computer thinking, but is a fundamental, inquisitive and abstract way of thinking that people have. It is a constructive and innovative way of thinking that leads to solving problems.

2.2. Scaffolding Teaching

The term "scaffolding" in scaffolding teaching is derived from the construction industry. The "scaffolding" in the construction industry is the working platform set up to ensure the construction process goes smoothly, while the "scaffolding" in the classroom is the effective teaching activities and materials adopted by teachers to help learners master new knowledge and promote their cognitive development. The idea of scaffolding teaching comes from the Soviet educator Vygotsky's theory of "the zone of proximal development". Vygotsky believed that teaching could eliminate the difference among the problems children need to solve and their actual abilities. This difference is the distance between the child's actual developmental level of independent problem solving and the child's potential developmental level of problem solving with the help of others. This difference is called "the zone of proximal development".

In order to help learners cross the current proximal developmental zone and reach a new cognitive level, teachers must provide appropriate clues and suggestions according to their cognitive situation and task characteristics. Meanwhile, teachers should help learners construct a conceptual framework or problem-solving model to facilitate the achievement of instructional goals.

In general, scaffolding instruction consists of three components, which are creating a situation, solving problem all together, and independent learning by children [5]. Currently, the five widely recognized components of the scaffolding model are scaffolding, contextualization, independent exploration, collaborative learning, and evaluation [6].

These scaffolding instructional process designs have the following commonalities: (1) Learner-centered. Scaffolding teaching seems to emphasize more on teacher's teaching, but this teaching must be driven by the learning situation, take the learner as the main learning body, and serve the cognitive development of the learner; (2) Stress effective teacher-student interaction. The effectiveness of teacher-student interaction is reflected in the fact that every question and answer between teachers and students should be inspiring. And the teaching activities and materials used by teachers and students should promote the achievement of teaching objectives and the development of students' cognitive level; (3) Provide appropriate "scaffolding". "Scaffolding" is instructional activities and materials that include learning examples, tools, discussions, and assessments. The difficulty of appropriate materials should be within the learner's proximal developmental zone. The learner can understand and master its content based on group work or teachers' reminders. These materials should be both interesting and knowledgeable. Appropriate teaching activities should be challenging and

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feasible, which can arouse learners' psychological needs and interest and enable them to learn proactively.

3. Scaffolded Teaching Design of Scratch for Computational Thinking Development

Guided by the concept of scaffolding teaching, this paper argues that teachers should provide various scaffolds for learners throughout the teaching process and constructs a scaffolded teaching model oriented to computational thinking development, see Fig. 1. In this model, the teacher is the facilitator who introduces examples, creates situations, proposes tasks, and provides resources, clues, and assessments based on task needs and student feedback. Students, as learning agents, should decompose tasks and organize resources based on various scaffolds provided by the teacher. In this process, students continuously adjust their thinking paths and methods, use tools and clues to complete learning tasks, and achieve the development of computational thinking.

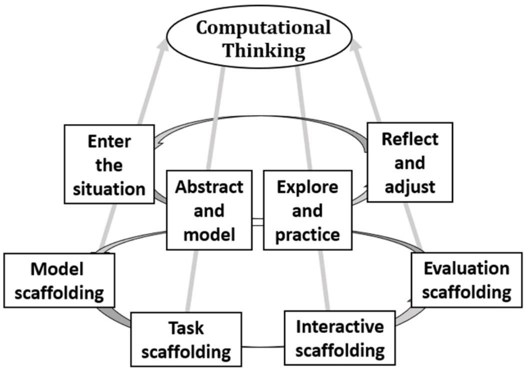

Figure 1. A scaffolding teaching model for the development of computational thinking

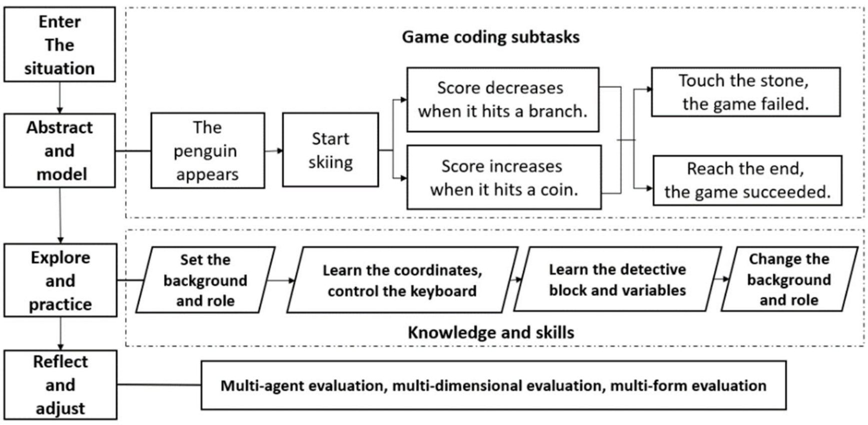

Figure 2. Scaffolding teaching process of *Penguin Skiing*

This study takes the design of the *Penguin Skiing* Scratch game as its theme. First, students are motivated to learn by trying out the sample game. Then, the teacher presents the *Penguin Skiing* programming task and helps the learners to break down the game task. In this process, the teacher must provide appropriate teaching and learning interactive scaffolds to help students build problem-solving models so that learners can complete the creation of the game while mastering new knowledge and developing computational thinking. The specific teaching process is shown in Figure 2.

3.1. Enter the Situation

First, the teacher needs to choose an appropriate example to build the background, that is, to create a learning situation and introduce the topic. The learning task of this lesson is to program the game Penguin Skiing. The player needs to control the penguin's movement with the keyboard. When the penguin hits a branch, the score will be reduced. When it touches a gold coin, it will score more points. If the penguin hits a rock, it will fall and the game will be over, otherwise it will reach the end and the game will be successful.

As shown in Figure 2, this game programming task involves knowledge points such as character's coordinates and appearance, detection block and variable settings. Penguin Skiing is similar to the code of Feeding Frenzy. However, it is more challenging than Feeding Frenzy with more knowledge points, for example, learners need to set the score variables and make the character move with the keyboard instead of the mouse.

The teacher takes Feeding Frenzy as an example for students to try out, which can stimulate learners' interest in learning. When students analyze its procedure after trying it, they can activate the task-related contents in their original cognitive structure. At this point, when the teacher presents the programming task *of Penguin Skiing*, learners will be confident and willing to accept the challenge.

3.2. Abstract and Model

This session is an important part of scaffolding learning and a core part of computational thinking development. After presenting the learning task, the teacher needs to use the task as a scaffold and keep asking focused questions to help learners break down the learning task into multiple smaller tasks and the master plan into multiple smaller steps. Through task scaffolding, learners are able to develop a more complete flow chart of the task and have an understanding of the internal logic of the game. As shown in Figure 2, by breaking down the task, learners can recognize that Penguin Skiing is an action game that contains two kinds of props, twigs and gold coins, and two endings, success and failure.

More importantly, learners need to abstract from descriptive language to procedural language in order to deepen their understanding of the task. For example, "the penguin starts skiing" becomes "the player manipulates the up, down, left, and right buttons to change the x and y coordinates of the penguin character", and "the score decreases when the penguin hits a tree branch" is transformed into "When the penguin character detects the branch material, the variable 'score' is reduced by one point". By transforming the language, learners try to abstract the fundamental problem from the redundant information, dig into the essence of the problem, and deepen their understanding of the program.

This process of decomposition and abstraction is the process of using computational thinking to solve problems and the process of developing thinking of the information technology course. Abstract thinking helps learners to grasp the essence of things, hide unnecessary details, and prevent them from being overwhelmed by problems in the subsequent coding process. Decomposition, on the other hand, splits a task into relatively independent subtasks, prompting learners to think about the knowledge points involved in each subtask, making the solution of complex problems simple and automatic.

3.3. Explore and Practice

This session is where learners explore and program on their own, and is a major part of scaffolding learning. The teacher needs to provide appropriate resources, such as music and character materials, according to the content of the task. At the same time, the teacher needs to provide problem-solving clues through teaching interactions, assist learners to complete the game subtasks one by one, and encourage them to innovate on the basis of transformation.

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Learners will eventually build a complete game program and form a systematic knowledge system. Through independent exploration and practice, the cognitive structure of learners is no longer a number of isolated and scattered knowledge points, but a closely connected dynamic schema.

As shown in Figure 2, each subtask of the "Penguin Skiing" game involves certain knowledge points. The teacher needs to help students master this new knowledge through effective instructional interactions. For example, learners have been able to make the character move with the mouse through coding in previous lessons. However, in Penguin Skiing, the penguin material should be controlled by the keyboard. At this point, the teacher should ask students questions to inspire them to think, such as "which keys on the keyboard do we usually use to control the movement of the game character" and "what variables can be set to specify the distance that the material moves with the keys". These questions provide clues for students to find solutions and are effective scaffolds for students to understand new knowledge.

In addition to learning new knowledge, learners need to activate problem-related content in their existing cognitive structures, innovate based on transformation, and solve problems flexibly. For the teacher, in addition to explaining the relevant Scratch coding knowledge, he/she should encourage and assist learners to explore and verify different solutions when they encounter difficulties. For example, in the first stage of analyzing the program of Feeding Frenzy, learners recognize that they can use the material detective block in the detection module to detect other materials. In Penguin Skiing, teachers should encourage learners to use the color detective block in the detection module to solve problems.

3.4. Reflect and Adjust

The scaffolding teaching concept advocates a diverse, multidimensional and master-multibody approach to assessment. Teachers and students should combine self-evaluation, peer evaluation and teacher evaluation when carrying out evaluation activities to examine comprehensively whether learners actively complete the learning tasks and use computational thinking to solve problems. At the same time, teachers and students should also evaluate the completeness, creativity, and knowledge of each game work to examine the learning outcomes comprehensively and objectively.

It is important to note that the "scaffolding" role of assessment can only be fully realized when it accompanies the whole teaching process. Scaffolding teaching requires learners to complete their learning tasks, but the purpose of learning is not to obtain a uniform "standard solution", but to enable learners to master subject knowledge and develop subject thinking in the process. In the process of scaffolding, teachers should continuously guide students to focus on the topic and break down the tasks, and evaluate learners' progress and attitudes as a whole. Learners need to regulate their own learning progress, examine the feasibility and rationality of problem solutions based on the effects presented by the game, and correct procedures that deviate from the goal. For learners, this process is one of self-monitoring, reflection and regulation, as well as the conscious use of metacognitive strategies that can effectively improve learning efficiency.

For example, in the evaluation session of Penguin Skiing, students can recommend the best work in their groups for display, and teachers and students can share the creativity and shortcomings of the works with each other. After the lesson, students will upload their works to the website, browse and praise each other, and evaluate the "Best Appearance Award" and "Best Creativity Award". At the end of the lesson, the teacher made a summative evaluation of the class's work and learning performance. The learners could have a comprehensive self-evaluation of their learning by filling in the Penguin Skiing task evaluation form, see Table 1.

Table 1. The self-evaluation form of *Penguin Skiing*

Questions	Poor	Normal	Great
My penguin will switch between multiple looks.			
My penguin moves as the player operates the keyboard.			
My penguin's score decreases when it touches a branch.			
My penguin's score increases when it touches a gold coin.			
My *Penguin Skiing* has both a failure and a fruitful ending.			
During the coding process, I am conscious of breaking down tasks.			
During the coding process, I use my previous knowledge to solve problem.			
During the coding process, I try to solve the problem in different ways.			
During the coding process, I consciously regulate the amount of time I spend.			
During the coding process, I am proactive in seeking help from my peers and teachers.			

4. Conclusion

In a Scratch programming course, teachers should provide learners with appropriate scaffolds based on their proximal development zone to create a situation that stimulates students' interest and motivation in learning. The task scaffolds and interactive scaffolds allow students to learn to transfer and innovate under the guidance of the teacher, and to develop problem-solving skills and computational thinking in the process of practice. The evaluation scaffolds motivate students to self-reflect and adjust, and improve the effectiveness of Scratch programming and their learning efficiency.

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