Research on the Design and Practice of Maker Educational Activities for the Cultivation of Computational Thinking

Zhangze Chen[1*], Jia Zhu[2],
[1] School of Education, Zhejiang Normal University, Jinhua, China
[2] The Zhejiang Key Laboratory of Intelligent Education Technology and Application
* zjnuczz@zjnu.edu.cn

Abstract: *As a crucial 21st-century competency, computational thinking (CT) has gained prominence in K-12 education. Addressing the weak CT cultivation and operational overemphasis in junior high schools, this study developed a CT development framework using Mind+ programming and McQueen educational robots through maker education activities. Experimental results from assessment scales and interviews demonstrate significant improvements in students' CT cognition and practical abilities, offering an effective approach for junior high CT education.*
Keywords: Computational Thinking, Maker Education, Mind+, McQueen Educational Robot

1. Introduction

The intelligent era has fundamentally transformed human cognition and lifestyles, making computational thinking (CT) cultivation a crucial educational objective (Wing, 2006). CT encompasses five core competencies: **abstraction, decomposition, algorithms, generalization,** and **evaluation** (Selby & Woollard, 2013). Currently, the cultivation of CT has been incorporated into technology courses around the world (e.g., Ministry of Education of China, 2020). While maker education integrated with CT shows potential for enhancing innovation and collaboration, practical implementation often prioritizes technical operations over cognitive development ("doing over thinking"). Therefore, this study integrates constructivism theory into maker education activities cultivated with CT, constructs a framework of maker education activities oriented to the cultivation of CT, and analyzes the effects of students' CT improvement from various aspects using scales, interviews, and students' works (Uzumcu & Bay, 2021). The analysis aims to answer the following research questions:

(1) What is the overall effect of the maker education model for cultivating CT on improving students' CT ability?

(2) Under the premise of using this teaching model, what are the different impacts on the five core aspects of students' CT ability?

2. Literature Review

2.1. The cultivation of CT

Since Wing's seminal definition of computational thinking (CT) in 2006, research has expanded across disciplines. The Computer Science Teachers Association (CSTA) established K-12 computer science standards in 2011, driving CT integration into STEM fields. Recent studies include Martin et al.'s (2024) 3C model for teaching coding and CT skills and Sun et al.'s (2023) educational gaming framework employing problem decomposition and process modeling.

2.2. Incorporating CT in Maker Education

Studies have developed multiple integration models. Li et al. (2024) positioned CT as an innovative thinking conduit for STEM-maker education synthesis, while Jiang et al. (2024) emphasized design thinking's catalytic role in value-driven maker projects. Both approaches employ project-based learning to cultivate collaborative problem-solving competencies, demonstrating pedagogical synergy. However, existing models predominantly prioritize practical implementation over theoretical underpinnings. Grounded in constructivism theory, this study establishes a CT-oriented maker pedagogy framework and empirically evaluates its multidimensional impacts on students' CT development in authentic classroom settings.

3. Research design

3.1. Theory model construction

Aligning with constructivism's dynamic epistemology (Fosnot & Perry, 1996), this study develops the **Ideation-Programming-Feedback** (IPF) model that systematically couples CT cultivation with maker pedagogy through three iterative stages. In the Ideation stage, learners define complex project problems and split them into sub-problems, developing abstraction and decomposition skills. In the Programming stage, learners collaboratively plan, draw flowcharts, and build prototypes, enhancing abstraction, algorithmic thinking, and evaluation abilities. In the Feedback stage, learners present their work, summarize functions, and optimize based on feedback, improving evaluation and generalization skills.

3.2. Participants

Participants (N=35) were eighth-grade students. According to Piaget's cognitive development theory, they are in the formal operations stage. Students here are curious but impatient, especially towards things they're not interested in. Yet, their abstract thinking is rapidly developing. So, the author thinks middle school - level maker education can enhance learning and CT levels. Also, pre-test showed most students have computer operation skills and have used graphical programming software, meaning they share a similar starting point.

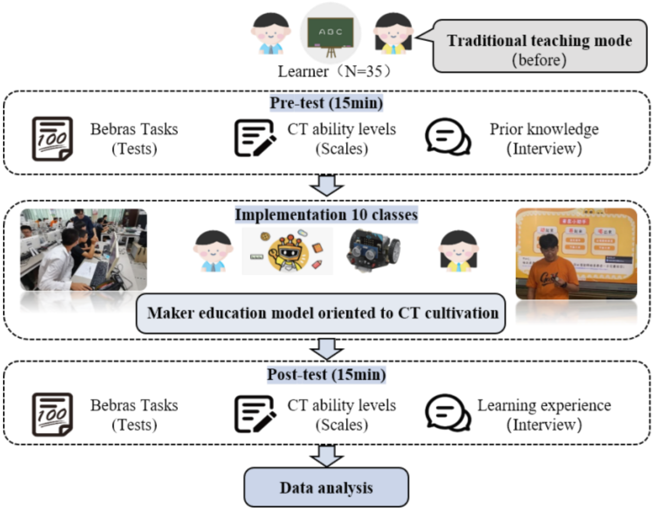

Fig.1 The research framework.

3.3. Study Design and Procedure

This research mainly uses Mind+ software as the basis for the maker course, and uses the McQueen educational robot as the starting point, aiming to cultivate students' CT. Using Mind+ combined with McQueen educational robots for maker teaching has greater advantages in cultivating students' CT than using graphical programming software or open-source hardware alone. At the same time, this study also uses a maker education model for CT cultivation. In the process of solving problems and completing project tasks, students continuously optimize problem-solving solutions and exercise their problem-solving abilities.

This study designed two projects with a total of 10 class periods, each class period was about 40 minutes. The teaching cases selected were from the STEM education series "Python and micro:bit Robot Programming for Middle School Students" published by Tsinghua University Press. On the basis of the teaching materials, the author made certain modifications according to the current situation of the learners and determined the teaching implemented this time. The cases were "My Fancy McQueen" and "Thread-Seeking McQueen"(as shown in *Figure 1*).

3.4. Data collection and analysis

To comprehensively assess students' computational thinking (CT) before instruction, pre-tests using Korkmaz's CTLS scale (12 items across 5 dimensions, 5-point Likert scale) and 5 Bebras Challenge questions (1 point each) were administered. Post-instruction analysis combined CTLS post-tests, performance assessments, and student interviews to evaluate CT development. Data analysis was conducted using SPSS 20.0, examining changes in CT cognition and problem-solving abilities through both quantitative (scale scoring) and qualitative methods.

4. Results

4.1. Bebras Tasks

This study used paired samples t-test to analyze the differences between pre-and post-test. The results showed significant differences ($p=0.04<0.05$) in the pre-and post-tests. The maker education model aimed at cultivating CT ($MD=3.57$, $SD=1.092$) obtained higher scores than the traditional teaching model ($MD=3.03$, $SD=0.985$).

4.2. CT ability levels

In this study, students' scores in five aspects of CT were statistically calculated in SPSS, and a paired sample T test was conducted to detect whether students' CT abilities have been improved. There are significant differences in the four abilities of Abstraction, Decomposition, Generalization, and Evaluation as well as the total score ($p<0.05$), but there is no difference in Algorithmic thinking ($p=0.16>0.05$). Among the five dimensions of CT ability Levels, the differences are most significant in Generalization and Evaluation. At the same time, it can also be seen from the table that the pre-test mean of the total score is smaller than the post-test mean.

4.3. Interview

This study conducted interviews with students to further understand how students play a role in self-exploration and group cooperation, as well as their mastery of relevant knowledge. More than 80% of students think they perform well under the maker education model. More than half of the students believe that under the maker education model for CT training, they can perform excellently in problem-solving and group cooperation.

5. Discussion and Conclusion

This study introduces the cultivation of CT in maker education, takes junior high school students as the research object, and constructs a maker teaching model oriented to the cultivation of CT based on constructivism theory, using Mind+ and McQueen educational robots for teaching practice. After two rounds of teaching practice and analysis of data and materials, the research results are now summarized:

(1) The maker education model oriented towards cultivating CT has a positive effect on improving students' CT ability.

This study used a maker education framework for CT cultivation. Analysis of students' CT pre-tests and post-tests, self-evaluation forms, and interviews revealed that the relevant teaching improved students' CT abilities, with significant gains in Generalization and Evaluation. Interviews suggested that in maker activities, students collect information, experiment, and adjust plans, naturally enhancing their inductive abilities. Maker projects, focused on problem-solving, require students to evaluate different solutions and choose the best approach, developing their evaluation and decision-making skills. Therefore, when designing maker education activities, teachers should guide students to focus on the learning and exploration process, not just the final results. Teachers should also facilitate reflection and sharing of learning experiences at the end of activities to further improve CT skills.However, no significant improvement was found in students' algorithmic thinking. This may be due to their prior exposure to similar programming tasks and a basic grasp of the course algorithms. As a result, students focused on practical operations and overlooked algorithm learning during maker activities. To address this, teachers can provide targeted guidance and algorithm resources to students who need them, encouraging deeper exploration of algorithmic concepts.

(2) Maker education can enhance students' attention and interest in information technology courses.

It can be seen from the interviews that students like this type of maker courses very much. In the traditional information technology teaching process, teachers often only impart basic knowledge and skills to students, resulting in students' lack of enthusiasm and interest in learning. However, if Mind+ is combined with McQueen educational robots, students can acquire corresponding knowledge and skills through creative projects, teamwork, etc., thereby improving their problem-solving abilities and stimulating their interest in information technology courses. Therefore, we can integrate more courses related to maker education into junior high school teaching, or adopt similar teaching methods to effectively promote the overall development of students.

Herein, this study explores the impact of the maker education model on the CT levels of junior high school students. In addition, recommendations for educational practice are provided. It is hoped that the content of this research can help the development of maker education in the future.

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