

Design and Implementation of the Robot Teaching Model Combining Maker Education and Project-based Learning

Zhiguo Li, Yanling Liao

School of Information Science and Technology, Yunnan Normal University, Kunming 650000, China

Abstract

Computational thinking is one of the core competencies in the teaching of information technology in middle schools, and programming design courses serve as an effective approach for cultivating computational thinking. How to foster students' computational thinking during the teaching of programming design courses is a crucial issue that urgently needs to be resolved in the teaching process. The article takes the junior high school robotics course as a carrier, constructs a teaching model and carries out teaching experiments using the concepts of "maker education" and "project-based teaching", aiming to explore whether this model can effectively improve students' computational thinking level. The study finds that with the support of the concepts of "maker education" and "project-based teaching", students' computational thinking level has been significantly improved.

Keywords

Maker Education; Project-based Learning; Robot; Teaching Model.

1. Introduction

Computational thinking is a problem-solving mindset that breaks down, abstracts, models, and algorithmically solves complex problems by translating them into logical processes a computer can handle. Programming courses are the most effective vehicle for this translation[1]. According to the 2022 Compulsory Education Information Technology Curriculum Standards for Grades 7–9, students must “read and process data from IoT-enabled devices through smart terminals or programs, then provide appropriate feedback or control.” This requirement obliges students to use computational thinking to decompose problems, abstract key elements, build data models, and implement algorithms via code. Computational thinking supplies the foundational logic for programming; every debugging session or feature optimization is, in essence, an exercise in reflection and iterative refinement within that mindset. Robotics courses—by integrating hardware and software in a cross-disciplinary, hands-on environment—align perfectly with the maker-education ethos of “learning by making” and with project-based learning’s emphasis on problem-driven, collaborative inquiry, thereby offering rich, multifaceted support for developing computational thinking[2].

2. Design of the Robot Teaching Model Combining Maker Education and Project-based Learning

Constructing an effective instructional model requires deliberate design of learning objectives, environment, assessment, and activities, and maker education—an approach that champions “learning through creating,” aims to cultivate diverse innovators, and is deeply infused with information technology—differs sharply from traditional paradigms by empowering learners to self-plan, self-manage, and self-evaluate within a supportive setting that foregrounds “learning by doing,” “learning by using,” and “learning by creating,” thus highlighting student

agency[3].Integrating these maker-education principles with the practical demands of contemporary robotics instruction yields a refined robotics-teaching model specifically suited to fostering middle-school students’ computational thinking (see Fig.1) that unfolds in four integrated phases: contextual lead-in, knowledge building, innovation & creation, and communication & sharing.

Compared with traditional pedagogies, the model’s key innovations are (1) student agency: learners set their own plans and collaborate accordingly; (2) built-in iteration: every activity is structured as a repeated cycle of prototyping, testing and refinement; (3) scaffolded creation: carefully designed supports guide students from guided practice to autonomous innovation; and (4) multi-dimensional assessment that blends continuous process evaluation with final-product appraisal through self-assessment, peer review and teacher evaluation.

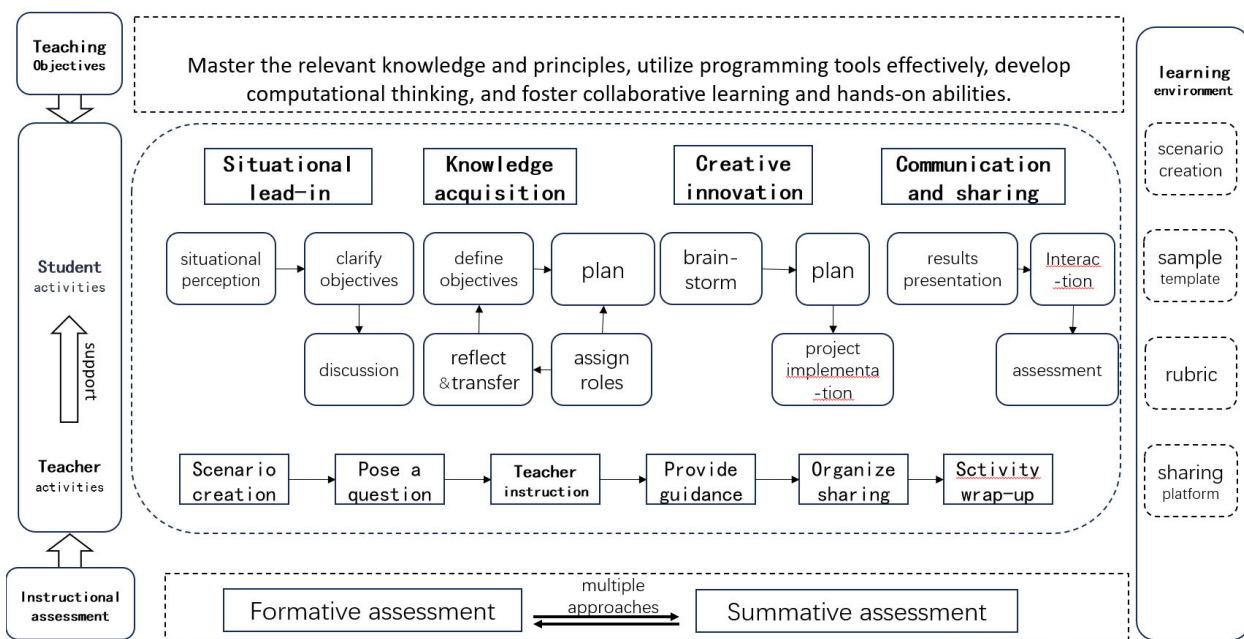


Figure 1. Instructional model diagram

2.1. Instructional Objectives

The robotics course is anchored in “learning by doing” and project-based learning, using student interest as its entry point to fully activate autonomy and creativity. Immersive hands-on practice allows learners to internalize foundational theory and tool use while progressing through abstraction, decomposition, modeling, and artifact realization. In this planned practice, students not only master the logic of translating theory into real projects but also systematically exercise computational thinking[4].

Situation Introduction: The primary goal is to shift students from passive reception to active construction, laying the psychological and cognitive groundwork for subsequent inquiry, practice, and innovation. A key challenge is selecting robotics projects that match the instructional entry point and can effectively spark student enthusiasm and interest.

Knowledge Learning: This stage serves as the bridge from theory to practice. Rather than merely “learning to operate,” students repeatedly cycle through a spiral of abstraction, decomposition, modeling, and realization. Guided by the principle of “needed for the project,” every concept is explicitly linked to upcoming practice. Core objectives include mastering the functions and collaborative logic of robot components, understanding the Input–Process–

Output workflow, learning to connect and debug programming software with hardware devices, and establishing the foundational insight that “software drives hardware.”

Innovation & Creation: This is the incubator where knowledge is transformed into innovative capability and the core of the entire instructional activity. Students advance from following prescribed steps to creating according to personal needs. Building on prior knowledge, they integrate hardware, software, and programming to conduct personalized innovation in robot appearance, structure, and function to meet real-world demands. Through the engineering cycle of “needs analysis → solution design → collaborative building → testing & optimization,” they cultivate computational thinking skills such as clarifying requirements, decomposing complex tasks, designing models, and implementing solutions. Clear role assignments—hardware design, software programming, and so on—within each group strengthen teamwork and responsibility. Creative expression is achieved through innovative appearance or interaction logic, culminating in the comprehensive goals of knowledge-to-practice transfer, core competency development, enhanced collaboration, and the fusion of technology and humanities.

Communication & Sharing: This phase makes student outcomes visible, thinking explicit, and competencies integrated. Through group showcases and cross-group interaction, learners clearly present their robots’ innovations in appearance, structure, and function along with the technical pathways, strengthening language expression and outcome-visualization skills; guided peer reviews based on scientific, artistic, technical, and creative dimensions foster constructive feedback and rational dialogue, deepening understanding of robot design. Discovering the multifaceted value where technology meets art cultivates technical aesthetics and responsibility, while peer recognition boosts innovative self-efficacy. Ultimately, collaborative and communicative abilities are advanced through structured group reporting and inter-group exchange, establishing an open, sharing classroom culture that celebrates the maker spirit and transforms individual group achievements into whole-class intellectual collisions and collective growth.

2.2. Assessment Design

Assessment follows a multi-method principle. Formative assessment focuses on artifacts generated during the project, whereas summative assessment targets the final robot product. Three stakeholder perspectives are used: group self-assessment, peer assessment, and teacher assessment. For formative assessment, the teacher mainly scores each group’s submitted learning-task sheets. Summative assessment takes place during the communication-and-sharing phase: every group presents its robot, while teachers and other groups rate the work simultaneously with a rubric. The final group grade combines self-assessment (20 %), peer assessment (30 %), and teacher assessment (50 %).

2.3. Instructional Activity Design

To align with junior-high students’ cognitive characteristics and course objectives, the robotics activities are structured around maker-education principles and project-based learning, progressing through “Contextual Lead-in → Knowledge Building → Innovation & Creation → Communication & Showcase” to spark interest and cultivate integrated competencies (see Table 1).

Table 1. Robotics Learning Activities Integrating Maker Education and Project-Based Learning

Teaching Stage	Students' Activities	Teachers' Activities
Situation Introduction	<p>According to the situation created by the teacher, watch videos or images to perceive the scenario.</p> <p>Think about the questions raised by the teacher and have group discussions to clarify the output of results in the later stage.</p>	<p>Create a learning situation through videos or images.</p> <p>Put forward questions to students and explain the task of this project to them.</p> <p>Combine with students' interests, provide scaffolds, and guide students to conduct data research.</p>
Knowledge Learning	<p>Based on the project materials and teacher's guidance, determine which structural designs and program designs need to be implemented for the basic functions of the robot.</p> <p>Have group discussions to determine the group action plan.</p> <p>Divide work and cooperate within the group for collaborative learning.</p> <p>After completing the basic tasks, summarize the current results to accumulate experience for the next step of innovation and creation.</p>	<p>Decompose the project tasks in terms of structure and program logic.</p> <p>Supervise each group to develop a plan and fill in the learning task sheet.</p> <p>Provide timely guidance and scaffolds during students' hands - on practice.</p>
Innovation and Creation	<p>Conduct group cooperative exploration, have a brainstorming session to collect good ideas and thoughts, and analyze their feasibility.</p> <p>The group develops a final robot creation plan and strictly implements it.</p> <p>The group divides work, cooperates, and practices hands - on.</p>	<p>Provide more project materials to inspire students' creativity and guide them to think.</p> <p>Patrol each group and provide timely guidance to students.</p>
Communication and Sharing	<p>Each group takes turns to present their works on stage, introduce the process of realizing the creativity, the difficulties encountered and the solutions. After that, the group fills in the work self - evaluation form to complete the self - evaluation.</p> <p>Each group listens carefully to the reports and shares of other groups, and fills in the work evaluation form to complete the mutual evaluation.</p>	<p>The teacher comments and summarizes the works of each group, helps students sort out the key points, and conducts a summative evaluation of the works.</p> <p>Collect and record the programs and robot works submitted by students.</p>

3. Evaluation of the Robotics Instructional Model

3.1. Student Product Scores

Product scores were collected and analyzed by group across three instructional cycles (see Fig.2). Each group’s final score was calculated as 20 % intragroup self-assessment + 30 % intergroup peer assessment + 50 % teacher evaluation.

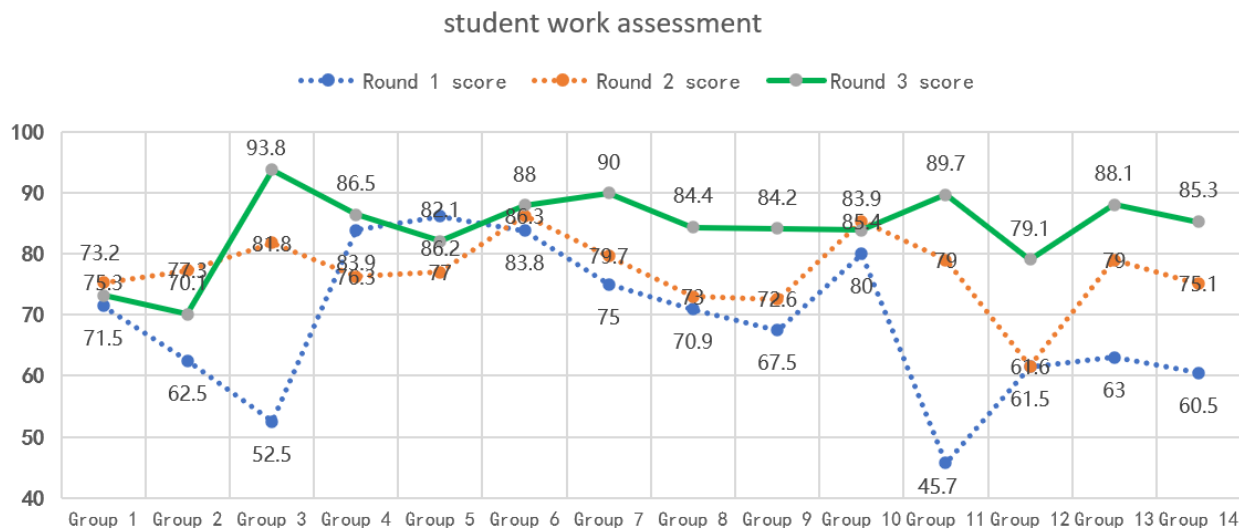


Figure 2. Statistical chart of student work scores

As shown in Fig.2, each round outperformed the previous one without any decline. On average, scores rose by 8.2 points between the first and second rounds and by 7 points between the second and third. Overall, students gained 15.2 points from the first to the third round, demonstrating clear and substantial improvement.

3.2. Student Computational Thinking Level

This study employed the Computational Thinking Scale (CTS) developed by Turkish scholar Korkmaz et al., assessing five dimensions: creative thinking, algorithmic thinking, cooperative learning, critical thinking, and problem-solving[5]. Pre-test results showed overall means of 3.38 for creative thinking, 3.62 for algorithmic thinking (the highest), and 2.93 for critical thinking (the lowest). After three rounds of the robotics course, post-test data revealed an overall average of 3.54: problem-solving 3.76, critical thinking 3.06, cooperative learning 3.62, creative thinking 3.50, and algorithmic thinking 3.78. Comparing pre- and post-test scores, every dimension improved, with cooperative learning showing the greatest gain.

4. Conclusion

Practice confirms that this instructional model not only markedly elevates students’ computational-thinking proficiency but also moves their artifacts from imitation to innovation. Interdisciplinary integration and a diversified assessment system foster teamwork and technological creativity, fully meeting the 2022 Compulsory Education Information Technology Standards’ call to “develop digital learning and innovation capabilities.”

As a micro-level reform of information-technology education, the project demonstrates the unique value of robotics in cultivating computational thinking: its hardware–software integration, problem-driven inquiry, and open maker culture provide a replicable solution to the challenges of core-literacy development in lower-secondary education. Future work will

expand robotics into broader contexts, deepen its convergence with AI and IoT, and continue exploring new possibilities for “technology-enabled education,” laying a solid foundation for nurturing innovative talent ready for the digital age.

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