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Original Paper

Integrating Maker Education into Primary Science: A Case Study of the "Ship Research" Curriculum with 3D Printing and Sensor Technology

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Abstract

This study develops an interdisciplinary primary science curriculum—"Ship Research"—guided by maker education principles, integrating 3D printing, graphical programming (Scratch/Arduino), and sensor technologies (water level/obstacle avoidance). A "knowledge-practice-iteration" pedagogical framework was implemented through contextualized project-based learning, supported by a multidimensional evaluation system (self-assessment, peer review, and artifact evaluation). Post-intervention assessments revealed significant improvements: students' confidence in hands-on skills increased by 7.5%, interest in scientific inquiry rose by 10%, and collaborative problem-solving capabilities were enhanced. The findings demonstrate that maker curricula enhanced by digital tools effectively foster innovation competencies in elementary students, offering a replicable model for transforming science education through technology-enabled creative practices.

Keywords

maker education, primary science education, interdisciplinary integration, 3D printing, project-based learning

1. Introduction

Primary school is the foundation of cognitive and creative development. In addition to teaching basic knowledge, science education also needs to stimulate students' interest in exploring, and cultivate their innovative thinking and practical ability. The elementary school science curriculum covers a wide range of fields such as material science, life science, and earth and environmental science, providing students with a wide range of exploration space and creation opportunities. As an emerging educational concept, Creative Education has emerged to provide strong support for the cultivation of innovative talents. Creative education emphasizes "learning by doing" and encourages students to closely integrate theoretical knowledge with practical operation through hands-on practice, creative design and problem solving, so as to cultivate their innovative thinking, creative ability and teamwork spirit (Sun, 2022).

Creative education takes digital technology as the content and means of education, and is a new education paradigm that integrates digital technology and education (Zhong, 2019). Foreign scholars believe that the classroom with various tools can be developed into a complete creator space, so that students can complete creative activities with perfect technical support (Eriksson et al., 2018); Creative education takes digital technology as both the content and the means of education, and it is a new educational paradigm resulting from the continuous integration of digital technology and education t (Halverson et al., 2014). Domestic scholars believe that creativity education is "learning by creating", which is a new type of education model supported by information technology to cultivate innovative talents, and emphasize the supportive role of the construction of creativity space for the development of creativity education (Liu, 2021); the popularization of creativity education requires systematic support in terms of the establishment of creativity education evaluation standards and supporting prerequisite courses, the development of teacher training, and the construction of creativity space. space and other aspects to provide systematic support (Ji, 2021). At present, the application and promotion of creativity education faces many challenges, such as the lack of professional teachers, insufficient investment in equipment, insufficiently refined curricula, small audiences, incomplete evaluation, and the lack of teacher training channels. To cope with these challenges, accelerating the construction of high-quality creativity curriculum, refining learning resources, developing appropriate teaching models, and improving the implementation effect have become the key to promote the development of creativity education.

Based on the model of creativity curriculum development, this paper takes the second unit of the textbook version of the second book of the fifth grade of elementary school science, "The Study of Boats", as a class example, and introduces technological tools, such as 3D printing technology, graphical programming technology, sensor technology, etc., to carry out the development and implementation of targeted teaching activities. It aims to explore the effective path of creativity education in enhancing primary school students' sense of innovation, creativity, learning styles, and ability to apply knowledge through specific project practices.

2. The Development of the Class Case of Creative Teaching Activities of the Study of Boats

The fifth grade "The Study of Boats" was chosen as a lesson example, considering that students already have a certain foundation in technology application, are curious about science and technology and life phenomena, and that boats, as a familiar thing, are easy to connect the knowledge points with life. The course is a material science section, and the content integrates knowledge of life, science, and technology, which makes it easy for teaching transfer and lesson case development.

This paper adopts the elementary school creator curriculum development model for the development of creator teaching activities in elementary school science curriculum, which links the theoretical foundation of curriculum development model with elementary school creator curriculum, and is divided into three levels: core level, element level, and development level. In this model, the development of the creativity curriculum unfolds along a circular process of curriculum objectives, development subjects, curriculum content, teaching strategies, curriculum implementation, and curriculum evaluation (Wan et al., 2017).

2.1 Curriculum Objectives

Scientific conception: to enable students to understand the process and use of simple handmade materials, and to master the factors that need to be considered when designing a small boat, such as the size, shape, and power system of the boat.

Scientific thinking: to develop students' ability to design a small boat according to the basic steps of experimental design, as well as the ability to continuously adjust and optimize the design according to the problems found in the testing process.

Exploration and practice: In the process of designing and producing the work, students will improve their problem-solving and engineering construction abilities, and encourage them to design and produce the finished experimental products according to their own creative ideas.

Attitude and Responsibility: Cultivate the attitude of students to dare to put forward their own views and be able to listen humbly to the reasonable suggestions of others, and at the same time, let the students understand that the invention of the boat has brought great convenience to the production and life of mankind.

2.2 Curriculum Content

The content of teaching creativity is very focused on contextualization, synthesis, and practice. The lesson “The Study of Boats” includes four main aspects: basic science knowledge, program design knowledge, 3D printing knowledge, and sensor application knowledge, and focuses on interdisciplinary integration (Figure 1).

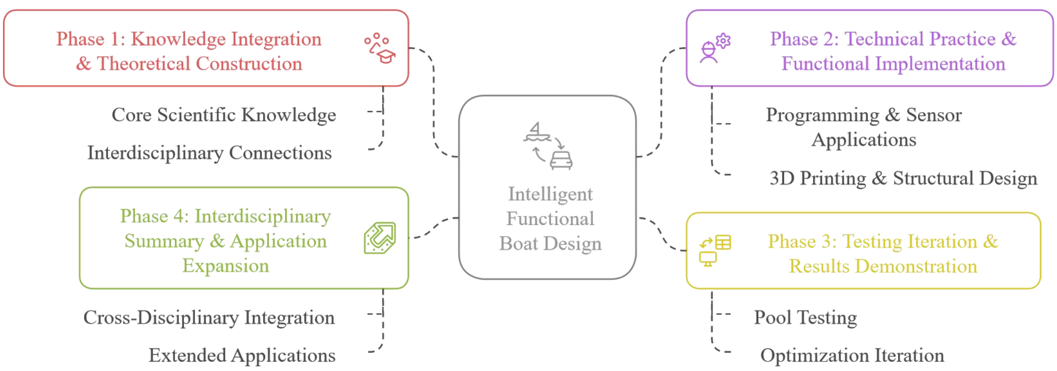

Figure 1. Intelligent Functional Boat Design Process

Basic science knowledge: The main focus is to help students integrate the fundamentals of boats (buoyancy, stability, propulsion methods, etc.) and the elements of boat design (size, shape, materials, etc.) through teacher presentations during the new lesson delivery session.

Programming and Sensor Application Knowledge: It is mainly a technical guidance provided by the teacher to students when they are building functions. This includes simple programming logic (conditional judgment, loop statements, etc.), programming software use (e.g., Scratch, Arduino IDE, etc.), and sensor types and functions (distance sensors, water level sensors, etc.), and guides the students to integrate the sensors into the boat to realize automatic obstacle avoidance, water level monitoring, and other functions.

3D Printing Knowledge: The main focus is on what students learn when they use 3D one to design and fabricate hull structures, including the basic principles and operating procedures of 3D printing, how to use 3D modeling software (e.g., 3D One) to design a hull structure and 3D print it.

2.3 Course Resources

The learning resources of this course can be mainly divided into two parts: online resources and offline resources, of which online resources include the principles of boat production, basic tutorials on graphical programming, 3D modeling hands-on training and sensor knowledge, etc. Offline resources include human resources such as teachers, peers, and equipment resources such as related hardware and software. Hardware and software mainly include 3D printing hardware and software, robotics components, graphical programming software and basic handmade materials, etc. Among them, 3D printing hardware and software include 3D one software and 3D printer, which are mainly used for hull structure design; robotics components mainly include temperature sensors, Arduino motherboards, water droplet sensors, motors, buzzers and other equipment, which are mainly used for the construction of hull functions; graphical programming software is mainly used for the construction of hull functions; graphical programming software is mainly used for the construction of hull functions. The graphical programming software is mainly used to set the intelligent program for the hull function; the handmade materials mainly include hot melt glue, propellers, hoses and other equipments, which are mainly used to help making other small parts.

2.4 Teaching Strategies

Life-oriented introduction: Showing various boats through videos or objects, let students feel the importance of boats in daily life and economic development, and stimulate interest and curiosity. Ask questions related to students' lives and guide them to think about the design elements of boats.

Game-based learning: Design Challenge, where students work in groups to design and build boats to meet specific functional requirements, to stimulate a sense of competition and teamwork. Through role-playing, students are given different tasks to enhance the sense of participation and responsibility in learning.

Inquiry-based learning strategies: Encourage students to ask questions and find answers by consulting information and experimenting for verification. Implement iterative design to continuously test, reflect and improve the design to promote knowledge sharing and stimulate innovative thinking.

Technology Integration: Interdisciplinary integration of knowledge from multiple disciplines, including physics, math, and information technology, to design boats using principles of physics, mathematical tools, and programming techniques. Use technology tools such as 3D printing and graphical programming software to help students transform their creative design into a physical model and experience the whole process.

Reflection and evaluation: Encourage students to evaluate each other's work and give input from a variety of sources. Guide students to write a learning journal to record ideas, challenges, solution strategies and learning gains in the design process, and to develop critical thinking and self-improvement skills.

2.5 Teaching Evaluation

Creative teaching evaluation should not only ensure the achievement of reasonable evaluation goals, but also promote teachers' teaching reflection and improve students' learning interest (Wan et al., 2017). In this case, four types of evaluation forms are designed, including the student self-assessment form for students' self-evaluation based on the analysis of indicators in various aspects of teaching activities; the student mutual evaluation form for group members to conduct comprehensive evaluation of other group members based on their practical, cooperative and other abilities under the guidance of the analysis of indicators; the student performance evaluation form to evaluate the students' performance in accordance with the four dimensions of innovative awareness, innovative ability, teamwork and interdisciplinary ability; the creator work evaluation form to evaluate students' performance according to the four dimensions of innovative awareness, innovative ability, teamwork and interdisciplinary ability; and the creator work evaluation form to evaluate students' performance according to the four dimensions of innovative awareness, innovative ability, teamwork and interdisciplinary ability. The evaluation form is used by teachers to make professional comments on students' creative works, and its evaluation criteria include four aspects: load-bearing, speed, aesthetics, and innovation.

3. Implementation of Creative Teaching Activities for the Study of Ships

3.1 Implementation Process

3.1.1 Project Initiation Stage

Students choose their own teams according to their personal interests and specialties, and teachers deploy them appropriately according to the needs of the team composition to ensure that each group has 4-6 members and that the team members complement each other in terms of their knowledge backgrounds, skills and personalities. Roles within the team include project manager, designer, programmer, tester, etc. to ensure that each member can take on specific responsibilities and tasks. The teacher explains that the ultimate goal of the project is to design and build a boat with specific features (e.g., automatic obstacle avoidance, water level monitoring, automatic water removal, automatic fire suppression, etc.). Develop a project timeline that identifies key steps such as preliminary design completion, 3D printing modeling, programming and sensor integration, testing and iteration.

3.1.2 Exploration and Learning Phase

Teachers need to organize the training of basic knowledge and technical tools. Through teacher's lectures and multimedia resources, students systematically learn the basic principles of the boat, design elements and other basic scientific knowledge. Through lectures or workshops, students master programming software (such as Scratch, etc.), 3D modeling software and the basic operation of sensors. Students collect relevant information according to the needs of the group project, such as examples of boat design and sensor application. The information is preliminary analyzed and organized to distill information and inspiration useful to the design.

3.1.3 Design and Production Stage

Preliminary design and 3D modeling: students determine the design of the small boat, including the hull structure, power system, sensor configuration and so on, according to the collected information and teacher's guidance. Use 3D modeling software to design the hull structure and make preliminary optimization and adjustment.

Power production and function building: Students refer to the propeller power principle and sample diagrams, use propellers, motors, batteries and other materials to make a simple propeller-powered boat, based on which they use temperature sensing, water droplet sensors, buzzers and other components to build the boat's automatic water removal, automatic fire extinguishing and other functions.

3D Printing and Finished Product Combination: After creating a hull model through a 3D printer, students effectively combine the hull, sensors, propellers, and other components to form a complete boat. After iterative testing and documentation, the boat is tested several times, test data is recorded, problems are identified and analyzed. According to the test results, adjust the design scheme and make iterative improvements to ensure that the boat can operate stably and realize the expected functions.

3.1.4 Presentation and Evaluation Stage

Each group demonstrates the boat in the class, introducing the design concept, production process and function realization. Evaluate the load-bearing and speed performance of the boat through the load-bearing and speed competitions. Groups evaluate each other's works and make suggestions in terms of creativity, practicality, aesthetics and technical difficulty. The teacher makes a comprehensive evaluation of the work. Students wrote a learning journal to reflect and summarize the whole project process and make suggestions for improvement. The teacher organizes a project summary for the whole class and encourages students to continue to explore and innovate in their future learning through recognition.

3.2 Analysis of the Implementation Effect

A Creative Literacy Assessment was conducted for fifth grade students in elementary school before and after the implementation of the lesson example. After the implementation of the lesson plan, the number of students who thought they had poor hands-on skills decreased from 30.0% to 22.5%, while the number of students who thought they had a chance to become a scientist increased from 27.5% to 45.0%, which indicated that the implementation of the lesson plan made the students have higher confidence in their own creativity. The percentage of students who enjoyed the experimental courses increased from 57.5% to 67.5%, reflecting that students enjoyed the self-designed and self-designed practical courses more. After the implementation of the lesson examples students are more inclined to choose the learning mode of peer communication and hands-on experimentation in the learning process, while the proportion of solving questions by asking classmates and teachers has increased, which means that students' sense of teamwork and communication has been cultivated. Through the teaching of the lesson example, the proportion of students who believe that knowledge has an impact on life has increased from 82.5% to 92.5%, which can be seen that the students' understanding of the living nature of knowledge has become more profound.

4. Conclusion

In this paper, with the concept of Creative Education, we chose the lesson of Primary Science "The Study of Boats" as an example, and designed the lesson case comprehensively from eight aspects: objectives, contents, equipment, strategies, requirements, evaluation, activities, and games. During the implementation of the lesson, students used 3D printing technology, sensor technology, and graphical programming technology to make the hull structure, build the function of the hull, and design the intelligent program, and finally summarized the knowledge of the lesson through the game activities and students' presentations, which stimulated the students' interest in learning and expanded their learning thinking. Through the assessment of students' creativity literacy before and after the implementation of the lesson, it was found that the development and implementation of this creativity activity has significantly improved the cultivation of students' creativity consciousness and practical ability, and fully improved students' cooperation and communication and problem solving ability. It is believed that with the strengthening of the practicality of the creativity course and the enrichment of the content of creativity teaching, the role of creativity education in the cultivation of students' creativity will become more and more prominent.

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