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Research on the Development of the "Beizhong Incense Burner" and Beidou Navigation Model and Marine Education Practice

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Abstract: This project integrates traditional Chinese craftsmanship wisdom with modern technology to develop an intelligent navigation model education system for teenagers. The core innovation lies in the creative transformation of the universal gimbal principle of the "Beizhong Incense Burner" to build a self-stabilizing system named "Beizhong Beidou". Using a 3D orthogonal dual-ring structure, the Beidou chip and solar panel remain horizontally stable at all times, ensuring reliable satellite signal reception and steady energy input. A "core–hull" decoupled architecture is adopted, with elastic rubber bands for energy dissipation and biodegradable bamboo materials to meet green development requirements. The curriculum follows the concepts of "problem-driven instead of story-driven" and "literacy generation instead of knowledge coverage", offering a progressive 5-module, 16-class system covering navigation initiation, hull mechanics, programming basics, Beidou navigation, and comprehensive practice. It cultivates students' engineering thinking and marine responsibility awareness. The project is expected to cover 20 primary and secondary schools and reach 2,000 students in the first year, forming a new "industry–education–research–application" collaborative paradigm for youth science and technology education, and cultivating talent reserves for the national strategy of building a strong marine country.

Keywords: Navigation model; "Beizhong Incense Burner"; Beidou system; Marine curriculum

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1. Introduction

The "Beizhong Incense Burner" pioneered a mechanical wonder in human technology [1]. As recorded in the *Records of the Western Capital* of the Western Han Dynasty, the "lying incense burner" invented by the skilled craftsman Ding Huan could be placed inside bedding and remain horizontal even as the bed moved [2]. The Western world first discovered this structural principle through Cardan, more than one thousand years later than China [3]. With an extremely simple structure adapting to complex motions, this invention remains the core configuration of gyroscopes, stabilization platforms and other precision instruments today [4]. The Beidou Satellite Navigation System is a global navigation system independently developed by China. Since its official launch in 2020, Beidou chips have been widely applied, featuring stable communication in base-station-free areas such as oceans, low power consumption, centimeter-level positioning, strong anti-interference and wide-temperature operation [5].

In 2022, important remarks emphasized that "building a strong marine country is a major strategic task for the great rejuvenation of the Chinese nation", pointing out the direction for marine technology innovation. The *Compulsory Education Science Curriculum Standards (2022 Edition* issued by the Ministry of Education also stresses "scientific inquiry and engineering practice", yet educational products integrating traditional culture and modern technology remain scarce [6,7].

This project deeply integrates the self-stabilizing mechanism of the universal gimbal with Beidou positioning technology to develop an intelligent navigation model education system for teenagers. Such integration not only promotes the creative transformation of outstanding traditional Chinese culture, but also serves as a concrete practice to "advance digitalization in education" [8].

By enabling teenagers to build navigation models integrating ancient and modern wisdom with their own hands, the project aims to cultivate a new generation of "little navigators" with engineering thinking, data awareness and environmental responsibility, and pass on the Chinese national marine spirit of "embracing all rivers and daring to strive and win" from generation to generation [9].

2. Design concept and innovations

The navigation model adopts a "core–hull" separated architecture. Guided by functional modularization, biodegradable materials and system self-stabilization, a full-cycle technical solution from manufacturing to drifting is constructed.

2.1. Decoupled overall architecture for extended service life

The model consists of two parts: a core module and a hull. The core module is the functional center integrating positioning, communication and energy subsystems. The hull is a biodegradable carrier providing buoyancy and protection. They are coupled by elastic rubber bands, ensuring structural integrity and functional decoupling.

This innovation breaks the integrated paradigm of traditional models. After the hull degrades, the core can drift independently, with mass reduced by about 60%–70%, draft depth lowered and drifting resistance significantly decreased. The system shifts from "hull-borne navigation" to "core-alone drifting", extending service life and reducing environmental load.

2.2. "Beizhong Beidou" self-stabilizing system

The heart of the core module is the "Beizhong Beidou" system, which creatively transforms the universal gimbal principle of the "Beizhong Incense Burner" [10]. The Beidou chip and solar panel are fixed on the inner ring platform. The outer ring is hinged with the core shell through orthogonal axes, forming a 3D orthogonal dual-ring structure.

The mechanical innovation is that no matter how the hull rolls or pitches under wave impacts, the inner platform always stays horizontal. The chip maintains optimal sky-pointing for reliable satellite signal reception, and the panel maintains maximum light exposure for steady energy supply.

2.3. Elastic rubber band energy dissipation mechanism

The "Beizhong Beidou" unit is connected to the geometric center of the core shell via elastic rubber bands, forming elastic constraints in five degrees of freedom: front–back, left–right, and down. The rubber band groups are symmetrically arranged along the 3D Cartesian coordinate system. When the core drops or collides, impact kinetic energy is absorbed through elastic deformation.

The rotational freedom of the gimbal and the translational freedom of the rubber bands are coupled to achieve multi-path impact energy dissipation. This design converts passive protection into active energy management. It has passed a 2-meter drop impact test, ensuring the reliability of core electronic components in complex waters.

2.4. Biodegradable bamboo hull with synergistic environmental and functional benefits

Bamboo is selected for the hull because it has a shorter growth cycle, faster growth rate and lower reforestation time and cost than other woods [11]. The project uses its natural fiber structure to balance biodegradability and structural strength [12]. Bamboo degrades within weeks to months in freshwater and decomposes into harmless organic matter after entering the ocean, avoiding microplastic pollution from traditional plastic models. It responds to the "green development" requirements in the *14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives Through 2035* [13]. The gradual degradation of the hull and continuous operation of the core form a time-sequenced coordination, reconstructing the product life cycle of "use–discard–continuous service" and providing a zero-pollution distributed node solution for water environment monitoring.

2.5. Integrated system with low power consumption and multi-mode positioning

The energy subsystem uses solar panels with low-power Beidou chips to achieve energy balance, with a typical power consumption of 25 mA @ 3.3 V. The positioning subsystem adopts the ATGM336H-5N module, supporting joint positioning of Beidou-2, Beidou-3 and GPS, stably outputting coordinate data even in remote ocean areas without base stations. The communication subsystem sends data back to a supporting mini-program, closing the loop from physical model to digital twin [14].

3. Research on curriculum module design

3.1. Curriculum objectives

The purpose of this course can be summarized into four dimensions: "Ocean Concepts, Ocean Thinking, Ocean Exploration, and Ocean Responsibility". The course is based on "Ocean Concepts", and through model-making practice, it helps students form an understanding of "the human community in the ocean". With "Ocean Thinking" as the method, it transforms system dynamics such as tides and wind directions into engineering design logic, cultivating the ability of systematic thinking. Through "Ocean Exploration" as the path, it conducts a 16-hour project-based learning to complete the engineering cycle from drawings to model-making. With "Ocean Responsibility" as the destination, it uses topics such as Beidou navigation and marine environmental protection to cultivate the sense of responsibility of "knowing the ocean, loving the ocean, and protecting the ocean".

3.2. Core concept shifts in curriculum design

The curriculum is based on two core concept shifts.

(1) Problem-driven instead of story-driven

Traditional marine education mainly narrates sailing stories, in which students receive information passively. Interest is aroused, but deep thinking is lacking. This course converts each story into a researchable core question:Zheng He's voyages → *Why could Zheng He's treasure ships sail far to Africa?* Columbus's discovery of the New World → *How to determine direction without seeing land?* Magellan's circumnavigation → *How to prove the Earth is round?* Students naturally acquire knowledge while seeking answers, rather than memorizing story details passively.

(2) Literacy generation instead of knowledge coverage

Traditional curricula pursue "full knowledge coverage", resulting in fragmented information and weak transferable application ability. This course focuses on core concepts and drives deep learning through project tasks.

Students ultimately gain transferable thinking and problem-solving abilities rather than scattered knowledge [15]. The curriculum design consistently asks: *What core literacy will students retain after completing this module?*

3.3. Progressive 5-module, 16-class system

Following the advanced path: *cognition foundation → practical construction → technology empowerment → cultural enlightenment → comprehensive application*, the curriculum is organized into five modules over 16 class hours.

(1) Navigation Initiation (Classes 1–3)

Core questions: *Why did humans venture into the ocean? What basic abilities are needed for navigation?*

This module answers the cognitive question of *why we navigate*. Starting from inquiry rather than stories, it guides students to derive three basic abilities: direction judgment, shipbuilding and material preparation. It then explores Zheng He, Columbus and Magellan.

The core literacy gained: understanding navigation as a systematic engineering project and developing exploratory thinking toward the unknown.

(2) Hull Mysteries (Classes 4–7)

Core questions: *Why can ships float and move forward? How can a ship sail stably as intended?*

This module is the core of engineering practice. It uses a challenge to lead students to discover buoyancy, center-of-gravity balance, streamlining and weighting. The four classes form a complete chain: buoyancy exploration → drawing design → prototype making → testing and optimization.

Students experience a full "design → make → test → optimize" cycle with quantifiable targets (tilt $< 15°$, load 50 g, waterproof 5 min).

The core literacy gained: the basic paradigm of engineering problem-solving, which can be transferred to any engineering or design task.

(3) Programming Introduction (Classes 8–10)

Core question: *How to make a ship sail automatically along a set route?*

This module bridges physical models and intelligent navigation. It explains that programming endows machines with decision-making ability rather than just issuing commands. The classes cover: how machines understand instructions → basic motion control → route execution.

The core literacy gained: computational thinking — decomposing complex tasks into executable sequences and debugging iteratively.

(4) Beidou Navigation (Classes 11–13)

Core questions: *How does a ship know its location? How to find a destination?*

This module is the technological highlight. It connects ancient star positioning with modern satellite positioning and reveals the nature of positioning: measuring distances to known reference points. It also naturally conveys the importance of independent technological innovation.

The core literacy gained: positioning thinking and understanding of the national strategic value of independent science and technology.

(5) Comprehensive Practice (Classes 14–16)

Core question: *How to comprehensively apply what has been learned to complete a full navigation mission?*

This module presents the final achievement. Students integrate hull balance, positioning and programming to complete a real navigation task. A formal "launch ceremony" marks the identity transformation from "learner" to "little navigator".

In summary, the curriculum features: question-chain-driven, literacy-goal-prioritized, engineering-cycle-integrated and comprehensive-practice-unified. The five modules are interdependent and jointly aim at the final "navigation challenge".

4. Expected impact and scale

According to the project survey, more than 70% of students show strong interest in marine life and national defense themes. Among them, 87.7% pay close attention to marine national defense and 72.9% are willing to learn more about marine life. The "Little Navigators" project turns such interest into practical exploration.

Notably, 40% of parents are willing to enroll their children in out-of-school science and technology courses, driven by children's interest and recognition of STEAM education. After experiencing the project, parents generally feedback that model assembly and curriculum design are "both fun and professional".

This two-way fit — students eager to learn and parents willing to invest — provides solid market support for the first-year target of covering 20 primary and secondary schools and reaching 2,000 students.

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