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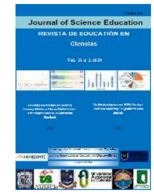

Kite Engineer: Aerial Photography System Design: A STEM Course Based on Problem-Solving in Authentic Contexts

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ABSTRACT

This paper is dedicated to designing a problem-solving STEM curriculum, using Aerial Photography System Design as the core task, and constructing an innovative teaching case centered on authentic engineering contexts. Across China, various regions are actively exploring approaches to promote STEM education, yet challenges in instructional design persist in teaching practices. The highlight of this curriculum lies in its emphasis on interdisciplinary integration and cross-disciplinary learning within a task-driven framework. The instructional design includes an analysis of learner characteristics, the establishment of clear learning objectives, and comprehensive planning of the teaching process, aiming to enhance students' abilities to identify, analyze, and solve problems. Strategies for curriculum implementation involve Centering on problem-solving and guided throughout by strategies for interdisciplinary integration, Establishing a mechanism for mutual support among partners, with group members collectively reflecting on and optimizing the product.

1. Introduction

Contemporary society is undergoing rapid transformation driven by new quality productivity. The formation and development of new quality productivity require unleashing scientific and technological innovation, the cultivation of high-level innovative talents being a key component. Through interdisciplinary projects conducted in Authentic Contexts, STEM education strengthens students' innovative thinking and problem-solving skills, encouraging their ability to propose innovative solutions, thus serving as a crucial means for addressing complex challenges under new quality productivity. Since the implementation of rejuvenating the country through science and education and strategy of strengthening the country through talent development, China's STEM education has achieved remarkable progress. However, certain shortcomings have also emerged, such as the imbalanced regional distribution of educational resources and an incomplete independent cultivation system for top-notch talents. (XIE, D, 2024). Development in science, technology, engineering, and mathematics (STEM) is widely emphasized worldwide. In the past decades, China has become the largest rising economy with a strong forward momentum in STEM advancement and education, which has profoundly impacted the global economy (Lei et al., 2023). Although STEM education has been proved to benefit students, there is a lack of understanding of instructional design for STEM education, despite the fact that such understanding is critical to research and to classroom practices. Limited understanding of relevant instructional design may lead to problems in implementing STEM education in the classroom (Halawa et al., 2024). How to naturally achieve deep interdisciplinary integration through the context of solving real-life problems and effectively enhance students' core competencies remains a common challenge in interdisciplinary practices. To address this issue, this case study presents a Real Problem-solving STEM Curriculum titled "Kite Engineer: Aerial Photography System Design", which integrates multidisciplinary knowledge through simulated engineering problem-solving and fosters students' inquiry skills and innovative thinking within collaborative teamwork.

2. Distinctive Concepts of Instructional Design

This case centers on the concept of problem-solving and begins with Authentic Contexts, establishing a closed-loop framework of "Sub-task Entry–Sub-problem Exploration–Learning Outcome Reflection". Through the design of the Driving Question—how to create a kite capable of stable flight while carrying a camera—students are guided to synthesize interdisciplinary knowledge, analyze and address sub-problems at each stage, complete the design and iteration of the kite product, and improve their Scientific Literacy and collaboration skills.

First, by setting the role context of a Kite Engineer, traditional Chinese culture is integrated into interdisciplinary instruction, helping students develop Cultural Confidence. During the entry phase, students explore the structural principles of kites and uncover the science behind flight; in the design and production phase, they learn traditional kite-making techniques such as bamboo framing and decorative painting; during the test flight and data collection phase, they experience unique flying methods and identify factors affecting flight stability; and in the Data-driven Design iteration phase, they come to appreciate the perseverance and dedication embodied

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in the Craftsman Spirit of traditional kite artisans. By blending modern technology with traditional craftsmanship, students form a multifaceted understanding of kite culture and engage in concrete actions for its preservation.

Second, a “Problem-driven–Knowledge Support–Competency Assessment” Three-dimensional Unit Structure is established. The unit’s overarching task is Kite Engineer: Aerial Photography System Design, with the central Driving Question being how to design a kite that can fly stably while carrying a camera at an altitude exceeding 10 meters. Subtasks follow an inquiry path of “Problem Definition–Design and Production–Test Flight Feedback–Solution Optimization”, while learning activities emphasize key stages including “Flight Data Analysis–Problem Attribution–Design Adjustment–Result Presentation”, together forming a bidirectional feedback mechanism between engineering practice and scientific reasoning. The learning activities integrate disciplinary knowledge of science, technology, engineering, and mathematics. By observing the flight status of kites, students formulate questions worth studying. They analyze flight stability using concepts such as Aerodynamics and Lift from a scientific perspective, model flight data and refine kite designs from a technological viewpoint, explore the placement of kite frames and techniques for attaching flying lines from an engineering standpoint, and apply knowledge of Axisymmetric Figures to address design challenges related to the kite’s surface and frame structure. Finally, through group inquiry and Result Presentation, students resolve sub-problems at each stage and produce tangible learning outcomes. In the unit instructional design, traditional kite-making is transformed into a project-based inquiry task that incorporates engineering design, Data Thinking, and collaborative innovation, cultivating students’ ability to comprehensively apply interdisciplinary knowledge, stimulating their scientific creativity, and guiding them to develop evidence-based scientific attitudes and cooperative team spirits.

3. STEM Teaching Design Based on Problem-Solving in Authentic Contexts

3.1. Learner Analysis

This case is designed for sixth-grade learners. From the perspective of knowledge and ability preparation, students have studied Axisymmetric Figures and data analysis methods in their mathematics courses during grades five and six, and they possess a certain level of reasoning ability and manual production skills. Moreover, through previous practical activities, they have accumulated experience in group collaboration and data analysis, enabling them to complete tasks under teacher guidance through group discussions and assigned roles. From the perspective of individual differences, some students have a basic understanding of kite structures and demonstrate critical thinking and transferable innovation abilities. However, most students lack an understanding of core physics concepts, are unfamiliar with traditional kite craftsmanship, and have limited experience in the processes of problem analysis and resolution. Therefore, teachers provide appropriate question prompts and Learning Scaffold at various stages of the project. For instance, during the entry task phase, teachers guide students in generating question lists and provide learning resources to help them understand kite materials, structures, and flight principles. During the kite test flight and data collection phase, when students encounter issues such as kites failing to take off or flying unstably, teachers assist them in recording key data—including kite area, weight, and string length—to identify causes and make necessary adjustments.

3.2. Design of Unit Instructional Objectives

The learning objectives of this unit are divided into four dimensions: knowledge and concept integration, problem-solving ability, scientific higher-order thinking, and social emotion and ethical awareness. First, at the level of knowledge and concept integration, students should understand the basic scientific principles of Aerodynamics and Lift, grasp the geometric relationship between kite shape and flight performance, and begin to connect geometric models with real-world applications. Second, regarding problem-solving ability, students analyze test flight data to identify variables affecting flight status, formulate hypotheses, and refine design proposals, thereby strengthening their analytical and problem-solving skills. Third, in terms of scientific higher-order thinking, students examine actual flight data to identify factors influencing flight performance, enhancing their data literacy and scientific reasoning ability. Throughout the project, they develop Engineering Thinking through processes such as needs analysis, physical prototyping, testing, and iterative improvement. Fourth, concerning social emotion and ethical awareness, students assume roles such as designer, engineer, and tester within group collaboration, build teamwork mechanisms, foster collaborative spirit, evaluate the feasibility of contingency plans through technical visualization of kite flight, and cultivate an evidence-based scientific mindset informed by data analysis.

3.3. Instructional Implementation: Subtask 4. Data-driven Design

This lesson addresses the challenge of “how to improve and design a kite that can fly steadily up to 10 meters high while carrying a 30-gram payload.” Students are required not only to consider Aerodynamics principles and the internal structure of the kite, but also to translate scientific principles into practical designs. Through continuous iteration, they will develop a kite suitable for high-altitude photography. During this lesson, students will complete the following tasks: based on data recorded during preliminary test flights and in conjunction with flight principles, identify and analyze the data, explore the functions of various kite components, determine the factors affecting flight performance, and work toward a standardized design.

- Create a scenario and clarify the task: The pre-class introduction is a crucial part of this lesson. Designing and constructing kites represents a relatively large-scale and challenging engineering task for elementary school students. To address this challenge, teachers have implemented two improvement strategies: ① advancing the kite design and development tasks so that students complete the construction and test flights before class and record relevant data; ②establishing learning scaffolds prior to class by presenting theoretical knowledge of kite aerial photography Result Presentation and demonstrating practical examples through teacher-led photo shoots to illustrate task feasibility and stimulate students’ interest in learning and research. Initially, the teacher displays videos of kite test flight created by student groups and guides them to consider: Is it feasible to use kites for aerial photography? Subsequently, the teacher presents the photograph of a Mosque in Old Delhi taken with a kite-mounted camera by a photographer from Indonesia named Nicholas (Figure 1), followed by images captured personally using a similar method. These examples demonstrate that kite aerial photography not only offers advantages of low cost and environmental friendliness but also eliminates the need to apply for flight permits as required for drones, thereby offering greater flexibility in capturing unique lighting effects and novel landscape perspectives from different angles. Finally, the engineering task for this lesson is clearly defined as follows: construct a kite capable of stable flight at an altitude of up to 10 meters while carrying a payload of 30 grams.

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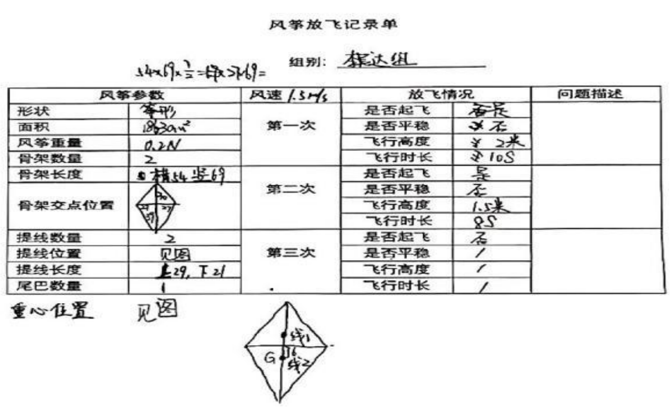
Figure 1. The photograph of a Mosque

• Identify problems and Influencing factors: After clarifying the problem context, learning objectives, and engineering tasks for this lesson, the teacher identifies and simplifies three core issues to be addressed: ① factors influencing the flight status of a kite; ② analyzing how each structural component of the kite affects these factors based on the design parameters of each group; ③ determining the criteria that define a standardized design for each part of the kite.

The central question in this phase is: "What are the factors that influence the flight status of a kite?" From an interdisciplinary perspective, this phase begins with the real-world engineering challenge of "Kite Engineer—Aerial Photography System Design", involving aerial photography systems. Scientific concepts such as Aerodynamics and force equilibrium provide theoretical support and scientific principles for kite design, helping students deepen their understanding of Lift. In mathematics, techniques for scaling axial symmetry figure and interpreting data charts offer practical guidance for product evaluation, assisting students in constructing basic geometric models and developing data literacy. The use of Kite Designer Software visualizes internal structural parameters and simulates kite flight, making product optimization more efficient.

In this phase, students are tasked with analyzing and comparing six sets of kite design parameters based on the kite model they designed and built in Subtask 2 (Figure 2), identifying factors affecting flight stability, and exploring how individual structural components influence these factors. However, due to limited understanding of the underlying theory, students may find it difficult to pinpoint the causes of unstable flight. To address this, the teacher provides supplementary materials on the physical principle of Lift, supporting students in grasping complex scientific concepts such as Aerodynamics.



风筝放飞记录单

54×69×½=[illegible] 组别：[illegible]组

风筝参数		风速 1.5m/s	放飞情况		问题描述
形状	筝形	第一次	是否起飞	是	
面积	1863cm²		是否平稳	否	
风筝重量	0.2N		飞行高度	2米	
骨架数量	2		飞行时长	10S	
骨架长度	横54 竖69	第二次	是否起飞	是	
骨架交点位置	(图)		是否平稳	否	
			飞行高度	1.5米	
			飞行时长	8S	
提线数量	2	第三次	是否起飞	否	
提线位置	见图		是否平稳	/	
提线长度	上29，下21		飞行高度	/	
尾巴数量	1		飞行时长	/	

重心位置 见图

Figure 2. Kite Flying Record Form

• Product Testing and Optimization: This stage centers on the core question: "What conditions should the components of a kite meet to constitute a standardized design?" Students are required to complete the following tasks through group collaboration: ① Optimize the structural design of the kite by summarizing experiences from the first structural model development and analysis, and by applying acquired mathematical and scientific knowledge, so that it can carry a 30g camera. ② Learn to use the Kite Designer Software, input numerical data of the kite's internal structures for modeling, thereby optimizing the design and validating the improved plan within a simulated wind field. ③ Each group should create design drawings and construct the kite based on successful simulation data. From the perspective of technology-enhanced STEM education, this stage integrates technical tools such as kite flight simulation software to assist students in kite modeling and feasibility testing. Data serves as the core driving force behind the development of science, technology, engineering, and mathematics. This strategy aims to guide students to extract valuable information from data, identify the scientific and mathematical issues behind each data point, and thus cultivate their data observation skills and application awareness. It also encourages students to maintain a rigorous scientific attitude when facing data outcomes, avoid blind speculation, and instead conduct objective analysis and judgment based on data, fostering a scientific spirit of inquiry.

Outcomes Communication and Reproduce: In this phase, the group's kite design is improved through group collaboration and Data-driven Design to identify an optimal solution. A representative then presents the group's design in the Kite Designer Software, followed by a discussion comparing the product before and after optimization. Outside of class, each group creates blueprints based on the successful simulation data and proceeds to build their kites, which can be used when spring arrives to capture satisfying photographs with their self-designed high-altitude photography system. This phase aims to help students further integrate theory with practice by utilizing software simulations and data analysis, applying their knowledge to hands-on exploration, and gaining a deep appreciation that kite design involves not only craftsmanship but also the integration of science and creativity.

4. Implementation Strategies for STEM Education Based on Problem-Solving in Authentic Contexts

4.1. Centered on problem-solving and guided throughout by strategies for interdisciplinary integration

When designing problem-solving STEM courses, instruction can begin with authentic problem contexts and incorporate engineering projects tailored to students' cognitive characteristics at their respective developmental stages. During the process of product optimization, principles of physics, Engineering Thinking, data analysis, and technical tools should be integrated. Taking this course as an example, students, having first developed an understanding of Aerodynamics, mechanical equilibrium, materials science, and geometric design, collect flight data through preliminary test flights. They then interpret the flying performance of kites based on analytical results, utilize Kite Designer Software to refine their designs, and enable the kite to carry a load and fly to a designated location, thereby making reasonable judgments or decisions and creating high-performance kites. This instructional sequence integrates the four disciplines—science, technology, engineering, and mathematics—throughout the entire problem-solving process. From a technological perspective, the precise data and simulation functions provided

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by the kite design software enable students to develop improvement plans that are more scientific and evidence-based. Throughout the inquiry process, teachers can ask timely questions and provide learning scaffolds to build connections between in-depth disciplinary knowledge and interdisciplinary breadth.

4.2. Establish a mechanism for mutual support among partners, with group members collectively reflecting on and optimizing the product.

STEM courses are collaborative, emphasizing mutual assistance and inspiration through group collaboration, thereby engaging in collective knowledge construction. In terms of group cooperation, teachers should cultivate students' teamwork spirit, knowledge, and cooperation literacy, guide the group to work together, and coordinate the spear within the group Shield; all team members are encouraged to participate (Aslam et al., 2023). When designing problem-solving STEM courses, the curriculum framework can be used to refine group division of labor tasks. By completing these tasks through teamwork, students are encouraged to engage in meaningful discussions, which helps reinforce their understanding and retention of the subject matter. In this course, for example, the teacher developed a framework centered on the design and optimization of kites, establishing a Kite Engineer learning environment. Students worked in small groups to gather and analyze learning materials, identify problems, and explore possible solutions. During the product optimization stage, each group member took on distinct roles—such as recorder, operator, analyst, or presenter—to assess the learning outcomes. Through both group discussions and classroom presentations, this approach improved overall classroom effectiveness while meeting the instructional goals aligned with core competencies.

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