Journal of Science Education Vol.26 n° 1 2025

Journal of Science Education

ISSN 0124-5481

Making Gift Boxes: A STEM Course Combining Hands and Brains to Design and Make

Wenye Zhang[a], Xinning Na[b*]

[a] Beijing Bayi School, Beijing 100080, China;
[b] College of Physics and Electronic Technology, Liaoning Normal University, Liaoning 116029, China

*Corresponding Author

ARTICLEINFO

Keywords:
Hand-brain combination
STEM courses
Mathematical modeling
2D 3D conversion

ABSTRACT

This course uses "making gift boxes" as the carrier to construct STEM project-based learning that combines hands and brains. Students integrate mathematical (cuboid features, area calculations), engineering (drafting, structural design) and artistic elements through the practice of measuring object dimensions, designing unfolding drawings, and optimizing material structures. The course adopts the modified 6E teaching mode, focusing on breaking through the spatial transformation thinking of two-dimensional plane and three-dimensional three-dimensional, and guiding students to go through the whole process of "problem raising→ mathematical modeling→ prototyping → iterative optimization". In solving real packaging problems (such as fragile goods protection and special-shaped object storage), we should develop spatial concepts, application awareness and innovation capabilities, realize the two-way empowerment of mathematical thinking and engineering practice, and reflect the interdisciplinary education value of "learning by doing".

1. Introduction

In the context of basic education curriculum reform, STEM education has become an important carrier for cultivating students' core literacy. Under the guidance of the core literacy of the " Compulsory Education Mathematics Curriculum Standards (2022) " , this course innovatively integrates mathematical modeling with engineering design thinking, and constructs a hand-brain combined design and production STEM course "Making Gift Boxes" (Bryan et al., 2015). Characterized by interdisciplinary integration and taking design and production as the main line, it constructs a teaching path of context, problem, exploration, and iteration, which effectively promotes the coordinated development of students' spatial concepts, application awareness, and innovation ability(Vasquez et al., 2013). Students not only need to use mathematical knowledge such as cuboid characteristics and unfolding diagram calculation, but also experience real design processes such as engineering drawing, material selection, and structural optimization, fully reflecting the core concepts of "learning by doing" and "learning by creating" in STEM education, and ultimately achieving a three-dimensional literacy improvement from mathematical abstract thinking to engineering practical ability (Resnick, 2017).

This case involves the combination of mathematical modeling and hands and brains. As a bridge between mathematics and the real world, mathematical modeling has a multi-dimensional promoting effect on cultivating students' " mathematical vision " and the combination of hands and brains. Through modeling practice, students can experience the value of mathematics in solving practical problems and stimulate their willingness to actively apply mathematics. The combination of hands and brains emphasizes the synchronous interaction of "hands-on practice" and "brain thinking". In the process of making gift boxes, students need to analyze the spatial structure (brain activity) through mathematical modeling, and then use tools to cut and assemble materials (hands-on operation) to form a process of " design action practice, practice reaction cognition " . The combination of hands and brains breaks through the barriers of traditional disciplines. For example, through tasks such as calculating the area of the unfolded diagram(mathematics), optimizing the product structure(engineering), and designing decorative patterns(art), it realizes the organic integration of mathematical logic, engineering thinking and artistic creativity In line with the requirements of the new curriculum standard " using mathematics to solve real problems " , abstract knowledge is transformed into concrete results (such as physical packaging boxes), helping students to establish a three-dimensional literacy system from mastering knowledge to improving ability and finally to core values. Through the collaboration between hands and brains, students can break through the limitations of "paper talk" and stimulate creative inspiration in the operation of real materials (such as using environmentally friendly materials to design deformable packaging). By taking advantage of the psychology of "students' desire for unknown and within their capabilities", students' interest in innovation and the practical innovation spirit of "daring to think and do" can be cultivated (English, 2016).

Accepted February 2025, Available online 30 July 2025

2. Teaching Objectives and Teaching Unit Design

2.1. Teaching Objectives

Through this unit, students will be able to use hands-on operations to solve the design problems of irregular object packaging boxes by using geometry and mathematics knowledge, cultivate spatial concepts, master the ability to reversely construct three-dimensional models through two-dimensional plane drawings (such as three-view drawings) (Uttal & Cohen, 2012). And understand the conversion logic between 2D and 3D graphics (teaching difficulties) (Battista, 2007); guide students to transform abstract concepts (such as geometric development drawings and material mechanics) into operational solutions (such as packaging box design drawings), and realize the practical internalization of knowledge in disciplines such as mathematics and engineering (Uttal et al., 2013). In teaching, teachers should encourage and guide students to use internal language while operating to cultivate mathematical thinking, and guide and help students to express internal language into correct oral language. After the operation, encourage students to express the operation process in groups or in the whole class. Then explain the thinking process according to the order of operation; and state the conclusion according to the results of the operation. This can combine the cultivation of students' language expression ability with the development of students' thinking ability 2). In the design of the box, the area and volume calculations are flexibly applied, and the concept of size ratio is established through physical measurement; design thinking is used to innovatively solve the spatial optimization problem of special-shaped objects, and the box type that meets the structural stability and material economy is designed; systematic engineering thinking is developed, and mathematical modeling, spatial reasoning and creative design are integrated to complete the whole process practice from object measurement, sketching to model making (learning focus). Finally, the spatial problem-solving ability and interdisciplinary practical ability based on mathematical principles are formed. Faced with the real situation of making packaging boxes, questions are raised and discussed to clarify what is a good question and improve the ability to discover and raise questions. Sort out the problems to form a research path with a problem chain as the order, and improve the ability to analyze problems. In the process of designing the plane diagram of the packaging box, the connection between two and three dimensions is established to develop the concept of space.

2.2. Unit Teaching Design

Mathematical modeling is not only mathematics education, but also "whole- person education". Its essence lies in achieving a deep dialogue between mathematics and reality through real-life problems. Its core is two mathematizations. The first is to transform practical problems into mathematical problem frameworks (model awareness), and the second is to abstract mathematical problems into specific mathematical models (model concepts) (Lesh & Doerr, 2003). This unit uses PPT to display Father's Day and Mother's Day promotional pictures to introduce learning topics, and requires students to design exclusive packaging boxes for school uniform bears and mugs to exercise students' hands-on skills and mathematical modeling thinking. This teaching situation derived from real needs effectively stimulates students' motivation to explore. In the first round of teaching, the teacher aroused interest by showing Father's Day and Mother's Day gift packaging cases, but in subsequent improvements, it was found that the integration of campus cultural elements can enhance students' sense of responsibility. The three-stage strategy of brainstorming, classification and standard construction is adopted in the problem-raising stage. The questions initially raised by students cover multiple dimensions such as size measurement, material selection, and decorative design. The teacher guides students to establish three standards: "research ability", "disciplinary relevance", and "engineering value". For example, for the two types of problems "measurement of cup handle length "and "stability of packaging box structure", students realized through group debate that the latter has more engineering thinking value. This standard-based screening process cultivates students" systematic problem awareness. The project adopts a modified 6E teaching model, which includes introduction, exploration, explanation, engineering, expansion, and evaluation (Chen & Chang, 2018). In the second round of improvements, teachers especially strengthened the systematic nature of the engineering design process. In the conceptual modeling stage, students abstract irregular objects into geometric bodies. In the prototyping stage, an iterative process from plane design to three-dimensional molding and finally to functional testing is adopted (Fig. 1).

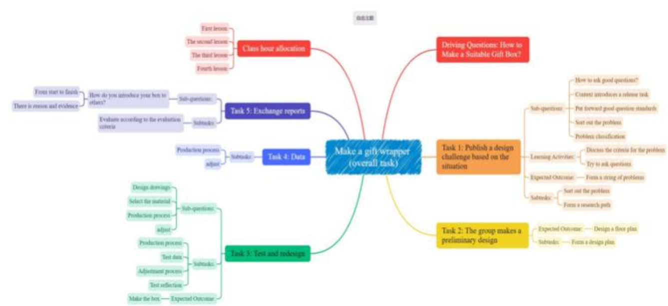

Figure 1. Teaching structure diagram

3. Teaching Implementation - Taking " 2 Lessons in Total – Preparing Materials to Making Gift Boxes" as an Example

3.1. Learner and unit content analysis

The teaching targets fifth-grade students, who have mastered the basic characteristics of rectangular prisms and cubes (the relationship between the number of edges, faces, and vertices), the types of unfolded diagrams, and the methods of calculating surface area (Fig. 2). Through the pre-test, it was found that students can raise multiple questions about "making a school uniform bear packaging box", such as size (such as "how big is the bottom area of the cup?"), material("choose anti-fall materials?"), and decoration ("how to design a pattern?"), but there are problems such as vague problem description (such as "how big should the box be?") and lack of systematic classification. Spatial imagination ability is at the concrete operation stage. Most students can independently complete the drawing of simple three-dimensional unfolded diagrams, but have cognitive difficulties in complex problems such as adhesive edge design and wrapping of special-shaped objects. Based on the "Rectangular prism (II)" unit of the fifth-grade second volume of the Beijing Normal University edition, the "Mathematics Fun "section is integrated, and the unit is integrated with the theme of "making cultural and creative product packaging boxes". The teaching content is divided into three levels, namely the basic level (length, width, and height measurement, unfolded diagram drawing), the application level (surface area calculation and material optimization), and the innovation level

Accepted February 2025, Available online 30 July 2025

(design of wrapping solutions for special-shaped objects) (Cunningham & Lachapelle, 2014）. The focus is on breaking through the spatial modeling thinking in the transformation between two-dimensional and three-dimensional, and cultivating mathematical modeling awareness through the complete project cycle of problem chain, design drawings, and physical models (Lesh et al., 2012).

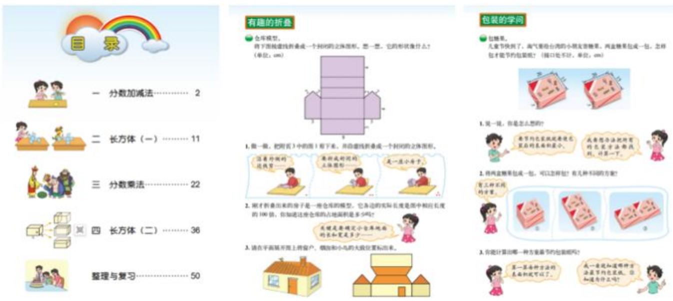

Figure 2. Unit content analysis

3.2. Teaching Process

·Scenario-driven, stimulating interest: Play Father's Day/Mother's Day gift PPT to show the important role of exquisite packaging boxes in conveying emotions through gifts, then present the case of damaged express boxes, "The ceramic cup that the teacher bought online last week broke during transportation. The problem lies in the packaging design." Finally, issue a driving question, "How to design a packaging box for fragile gifts that is both beautiful and safe?" At this time, students watch the PPT and discuss spontaneously, and put forward observations when analyzing the damaged cases. The group quickly brainstorms, "What factors need to be considered for safe packaging?" "How to use mathematical knowledge?" Evoke emotional resonance through holiday scenarios, use real problems to trigger cognitive conflicts, and activate students' life experience with three-dimensional figures.

·Knowledge sharing, problem focus: teachers distribute common packaging boxes(rectangles, cubes, cylinders), organize disassembly and observation activities, build knowledge scaffolds "the relationship between the unfolded diagram and the three- dimensional structure" and "surface area calculation method", guide problem classification "post your group's problems to the three areas of size calculation, material selection, and structural design", and debate when measuring and recording "Should the interface part be included when calculating the amount of paper used?" "The mathematical calculations for cylindrical packaging are more complicated", classify problems, and classify "Does the thickness of the material affect the load-bearing capacity?" into the material area; "How to save the most packaging paper?" into the calculation area. This stage aims to establish geometric intuition through physical operations, cultivate systematic thinking in problem classification, and establish a clear framework for subsequent exploration (Feder et al., 2009).

·Elements sorting and innovative thinking: The group sorts out the problems to form a research path. The teacher presents the learning tasks, classifies the problems according to the standards, sorts out the problems to form a research path, and the students communicate in groups according to the tasks, diverge their thinking, and are not bound by the common packaging boxes in daily life. This allows students to have wild ideas and improve their understanding of the problems in the process of classifying and sorting the problems according to the standards, and develop preliminary ability to analyze and solve problems (Beghetto, 2017).

·Experimental practice, design and production: the teacher assigns tasks, asking students to try to design packaging boxes, think about the data needed for the design and measure, and ask students to draw the design. Due to class time constraints, the assignment is assigned in class, and students complete the design of the packaging box after class, so that students can deepen their understanding of the characteristics of rectangular prisms and cubes in the measurement process,

and develop spatial concepts in the process of drawing plane design drawings (Papert, 1980). Improve the design drawings and make packaging boxes, and record new problems found during the production process.

·Group cooperation, evaluation design: Students work in groups to independently raise questions (such as size calculation, material selection, and structural design) around the real situation of "making gift boxes" (such as Father's Day gifts and school cultural and creative products). Through discussion, "good questions" (must meet the standards of "cannot directly see the answer" and "research value") are screened out and classified (such as size, material, and decoration). This can not only mobilize students' enthusiasm, but also enable students to better participate in the class. Evaluation and thinking cultivate critical thinking. Before sorting out the questions, teachers and students jointly build evaluation standards to enable students to clarify their thinking direction. Through comparative analysis of the questions, they can reflect on themselves and evaluate each other, which is helpful to cultivate students' independent learning ability and critical thinking (Table 1). Continuous exploration deepens understanding, encourages students to raise sustainable research questions, and continue to conduct cooperative exploration after class and report in the student lecture hall, which helps students to think continuously, deepen their understanding of the construction of the meaning of scores, and develop research habits (Shepard, 2019).

Table 1. Learning evaluation indicators

Evaluation dimensions	Evaluation criteria
1	I can understand the background, purpose, and requirements of the task
2	I can ask questions based on the situation, classify the questions according to the criteria, and identify the core issues of each type of problem
3	I can accurately judge the corresponding parts of each side and edge of the box and their position
4	I learned about the type of box box and I could see how the box box was different from the box plan (where the bond) was
5	I can determine the length, width and height of the cuboid box I made according to the size of the gift, so that the size of the cuboid box I made is in line with the accommodation of the gift and the material is saved
6	The box I made is very strong, and the pattern of the box is related to the art design of the text and the school culture, which is creative, beautiful, and can attract attention
7	I was able to make a cuboid box using mathematical knowledge such as cuboid features and unfolding diagrams, and I fully felt the application of mathematical knowledge in daily life

4. Summary and Reflection

Project-based learning is centered on the core concepts and principles of the subject, placing students' learning in real problem situations, using multidisciplinary knowledge and methods in the form of teamwork to independently explore and solve problems, thereby improving comprehensive literacy . This course takes "hand-brain integration" as the core, and through the real project of "making gift boxes", it deeply integrates mathematical modeling, engineering design, artistic expression and technical practice, and explores the innovative path of "unity of knowledge and action" in STEM education. In the implementation of the course, students go through five

Accepted February 2025, Available online 30 July 2025

processes: problem definition, data measurement, model construction, physical production, and test iteration, fully reflecting the two-way empowerment of hand-brain collaboration. Through the creation of life-like situations such as “Father’s Day Gifts” and “School Cultural and Creative Products”, students’internal driving force for exploration is activated; with the help of engineering challenge tasks such as “two- dimensional plane design and three-dimensional stereo conversion” and “material optimization and structural stability”, a bridge between mathematical concepts and life practices is built, effectively developing students’spatial imagination and mathematical modeling awareness. Students showed three types of advanced performances: the basic level can accurately measure data and complete the production of standard rectangular blocks; the development level can independently design special-shaped packaging to meet the storage needs of special items; the innovation level tries to use topological principles to develop deformable and environmentally friendly packaging. The “Making Gift Boxes” unit will continue to optimize the integration path of intelligent education scenarios, build personalized learning maps, and establish a diversified evaluation system.

References

Battista, M. T. (2007). The development of geometric and spatial thinking. Second handbook of research on mathematics teaching and learning/National Council of Teachers of Mathematics.
Beghetto, R. A. (2017). Creativity in teaching.
Bryan, L. A., Moore, T. J., Johnson, C. C., & Roehrig, G. H. (2015). Integrated STEM education. In STEM road map (pp. 23-38). Routledge.
Chen, Y., & Chang, C. C. (2018). The impact of an integrated robotics STEM course with a sailboat topic on high school students’ perceptions of integrative STEM, interest, and career orientation. EURASIA Journal of Mathematics, Science and Technology Education, 14(12), em1614.
Cunningham, C. M., & Lachapelle, C. P. (2014). Designing engineering experiences to engage all students. Engineering in pre-college settings: Synthesizing research, policy, and practices, 21(7), 117-142.
English, L. D. (2016). STEM education K-12: Perspectives on integration. International Journal of STEM education, 3, 1-8.
Feder, M., Pearson, G., & Katehi, L. (Eds.). (2009). Engineering in K-12 education: Understanding the status and improving the prospects. National Academies Press.
Vasquez, J. A., Cary, S., & Comer, M. (2013). STEM lesson essentials, grades 3-8: Integrating science, technology, engineering, and mathematics. (No Title).
Lesh, R. A., & Doerr, H. M. (2003). Beyond constructivism: Models and modeling perspectives on mathematics problem solving, learning, and teaching. Routledge.
Lesh, R., Hoover, M., Hole, B., Kelly, A., & Post, T. (2012). Principles for developing thought-revealing activities for students and teachers. In Handbook of research design in mathematics and science education (pp. 591-645). Routledge.
Papert, S. (1980). Children, computers, and powerful ideas (Vol. 10, pp. 978-3). Eugene, OR, USA: Harvester.
Resnick, M. (2017). Lifelong kindergarten: Cultivating creativity through projects, passion, peers, and play. MIT press.
Shepard, L. A. (2019). Classroom assessment to support teaching and learning. The ANNALS of the American Academy of Political and Social Science, 683(1), 183-200.
Uttal, D. H., & Cohen, C. A. (2012). Spatial thinking and STEM education: When, why, and how?. In Psychology of learning and motivation (Vol. 57, pp. 147-181). Academic Press.
Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). The malleability of spatial skills: a meta-analysis of training studies. Psychological bulletin, 139(2), 352.

Accepted February 2025, Available online 30 July 2025