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Comprehensive Mutilation of Marine Resources: Freshwater Acquisition in the Sprat Islands: A Project-based Science and Engineering Practical STEM Programme

Xiaomeng Song[a], Jiahuan Cao[b]

[a] *Beijing Bayi school, Beijing 100080, China;*
[b] *Liaoning Normal University, Dalian 116000, China*

A R T I C L E I N F O

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A B S T R A C T

This paper focuses on the interdisciplinary project-based STEM course titled "Comprehensive Utilization of Island Marine Resources." It sets four teaching objectives: interdisciplinary knowledge integration, cultivation of scientific concepts, engineering thinking and quantitative analysis, and social decision-making skills. The course is divided into three sessions to clearly define the core task of "desalination." In the second session, flash evaporation and membrane separation technologies are introduced to analyze the feasibility and efficiency of obtaining freshwater on islands and reefs. In the third session, solutions are optimized from the dimensions of cost, environment, and policy. to cultivate engineering thinking. Additionally, a three-dimensional, multi-faceted evaluation system is established, encompassing peer evaluation within groups, inter-group evaluation, and performance-based evaluation, to enhance students' core competencies. In terms of implementation strategies, the course identifies interdisciplinary themes based on curriculum standards, uses real-world projects to drive immersive learning scenarios, integrates scientific principles with technological applications, and incorporates mathematical modeling to foster quantitative thinking and engineering capabilities.

1. Introduction

STEM teaching is a comprehensive course that organically integrates science, technology, engineering and mathematics, and it is an educational concept and teaching mode based on discipline integration, project-based learning and practical problem solving, emphasizing both knowledge and ability, and featuring interdisciplinary, conceptualization, cooperation and innovation (Purnomo et al., 2025). The Compulsory Education Science Curriculum Standard proposes that different disciplines "have differences in research methods and share some common scientific methods, showing the trend of mutual penetration and cross-fertilization" (Jacqueline et al., 2025).

Project-based teaching is to build a model based on real project tasks, emphasize the transformation of teaching content into operable and exploitable project models, cultivating students' ability to discover and solve problems (Fathiya Al Kamzari & Norlidah Alias,2025), and stimulating students' higher -order thinking and creativity in the process of carrying out the project. The combination of these two teaching modes can largely combine the advantages of both, achieve twice the result with half the effort, and further promote the innovative development of educational technology.

"Comprehensive Utilization of Marine Resources on Islands" is an interdisciplinary project-based STEM course based on higher-order thinking in science (Nyadjro et al., 2025). In terms of course design and implementation, interdisciplinary fusion of knowledge was achieved at the initial stage by deeply integrating the relevant contents in the multi-disciplinary curriculum, and then technology application and higher-order thinking were gradually introduced (Dingliang Tan, 2025) and the related points of the standards of of the standards of various disciplines were mined to "island freshwater", of the standards of various disciplines were mined to "island freshwater", "island freshwater", "island freshwater", and "island freshwater". By exploring the related points of the standards of each discipline, and taking real problems such as "the acquisition of fresh water on islands", "how to develop and use marine resources on islands" and "the strategic significance of the development and use of marine resources on islands" as the guide (Yan Dong et al., 2025). We combine the knowledge of the disciplines of chemistry, physics and biology with the science and technology of flash evaporation and membrane separation, and introduce mathematical modelling. Combining the knowledge of chemistry, physics, biology and other disciplines with science and technology such as flash evaporation and membrane separation, and introducing mathematical modelling for quantitative analysis, the curriculum has shifted from a single-discipline perspective to a multi-dimensional framework for solving complex problems (Wenbo Deng et al., 2025).

With the deepening of STEM education from "interdisciplinary knowledge integration" to "real problem-driven system integration", relying on the project-based learning mode in real situations, the all-round integration of fragmented

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disciplinary knowledge is evolved into a tool for solving engineering problems, and quantitative analyses are introduced to achieve the goal from chemical principles to quantitative analyses, and to achieve the goal from chemical principles to quantitative analyses. Quantitative analysis is introduced to realize the logical closed loop from chemical principles to physical methods, combined with mathematical modelling towards biological governance (Zhaorong Tao, 2025). Integrated Utilization of Marine Chemical Resources Engineering on Sea Islands is based on interdisciplinary knowledge integration of chemical separation methods, physical pressure principles, biofilm technology, mathematical modelling, etc., and integrates the multi-dimensional synergy of Science, Technology, Engineering and Mathematics, with the core objective of cultivating students' practical engineering ability and higher-order thinking. The core objective is to cultivate students' engineering practice and higher-order thinking (Zhuoyu Zhao, 2024).

2. Interdisciplinary teaching design based on project-based learning

2.1. Learner Analysis

Students usually learn the relevant knowledge required by the "standard" of physics, biology and geography in the seventh and eighth grades, and they know the inter conversion of the three states of matter and their microscopic causes, and the accompanying heat absorption and exothermic phenomena; they understand the characteristics of fish and the vertebrate animals from the perspective of biodiversity; they know that there are many forms of energy, such as mechanical energy, internal energy and solar energy, and they know the conservation of energy and exothermic phenomena. energy, know the conservation of energy and the existence of a transformation relationship between. In Grade 9 Chemistry, they learn about the composition and comprehensive Mutilation of fossil energy sources, and understand the essential causes of the separation of water, solutions and substances from a microscopic point of view. Based on interviews, examination results and experience, students often have the following disciplinary or interdisciplinary obstacle points: lack of understanding of the relationship between science and engineering technology, insufficient experience in synthesis interdisciplinary concepts, mathematics, and technology to solve practical problems, lack of awareness and ability to innovate, and lack of understanding of the central position of scientific and technological innovation in the overall situation of China's demonstration; insufficient understanding of the concept of resources, exertion of subjective initiative, and the comprehensive use of natural resources and indifference to the awareness of participating in social decision-making. Therefore, teachers need to play a guiding and supporting role to help students clarify the project objectives, provide project resources appropriately, and implement the division of labour in each group to promote core literacy (Murimo Bethel Mutanga, 2024).

2.2 Teaching objectives

From the perspective of cultivating the integration of interdisciplinary knowledge and the ability to apply interdisciplinary knowledge, through the comprehensive use of seawater for energy supply by marine power resources and mineral resources, and the relationship between marine biological resources and the human body's energy, etc., to understand the mutual transformation between solar energy, chemical energy, internal energy and mechanical energy, and to form the idea of energy transformation and conservation; from the perspective of cultivating the concept of science and scientific thinking, through the transformation of seawater chemical resources, From the perspective of cultivating scientific concepts and scientific thinking, through the transformation of seawater chemical resources, the relationship between nutrients contained in marine biological resources and the human body, we can understand the reasons for material changes from a microscopic perspective, establish the understanding of the conservation of elements and the transformation of substances, enhance the view of particles, the view of elements, and the formation of the view of transformation, and realize that human beings can play the role of subjective initiative to protect and transform the material world. From the perspective of cultivating engineering thinking and quantitative analysis ability, through the design and evaluation of seawater comprehensive Mutilation field, we can simplify the practical problems into suitable physical models, combine the core knowledge of the discipline, mathematics and technology, feel the relationship between science and engineering technology, understand the core position of scientific and technological innovation in China's demonstration, and enhance the awareness and ability of innovation. From the perspective of cultivating social decision-making ability and awareness of resource exploitation and Mutilation, through designing and completing the project on comprehensive Mutilation of marine resources, The students will understand the importance of resources for human beings, the country and the earth, recognize the significance of exploiting, insisting and protecting marine resources, and have the willingness and confidence to utilize natural resources in a comprehensive way with their own initiative and to participate in decision-making in society (Soobin et al., 2025).

2.3. Project-based learning process design oriented by engineering thinking - overall teaching planning of the unit

The case of "South China Sea islands fresh water acquisition" as the theme of the project, divided into three lessons layer by layer: first, the integration of chemical separation and physical boiling point knowledge, combined with the overview of marine resources and international regulations to design the project programme, to guide the students to clarify the core tasks of the project; and then, the introduction of flash evaporation, membrane separation technology, combined with the use of current science and technology, students in small groups to work together on the project. Then, introducing flash evaporation, membrane separation technology, combined with the current use of science and technology, students select islands and reefs in small groups, explore the principles of the technology through experiments and analyse the feasibility of the scheme through mathematical models; finally, systematically integrate the cost, environment, policy and other dimensions, deepen the quantitative analysis by using the mathematical efficiency formula to improve the project scheme, and comprehensively improve the students' engineering thinking and comprehensive practical ability (Margaret et al., 2025).

Lesson 1: In-depth integration of interdisciplinary knowledge, integration of chemical separation and physical boiling point knowledge, and design of the project theme of "Freshwater Acquisition". Teachers introduce the overview of the South China Sea islands and relevant international legal rules, students' preliminary understanding of the overview of marine resources, marine resources are divided into marine power resources, marine biological resources, marine mineral resources and seawater chemical resources, through group analysis and discussion to understand the strategic significance of the South China Sea islands comprehensive utilization of marine resources project, economic interests and the

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significance of the promotion of scientific and technological development; combined with the questionnaire survey after the class, after the analysis and discussion It is clear that the primary task is to obtain fresh water, i.e. to utilize the water resources in seawater chemical resources by using other resources in the ocean.

The core objective is to establish project cognition, combine the overview of the South China Sea islands with international regulations and and the significance of the comprehensive use of resources to determine the project theme, and make clear that the core issue is the use of marine resources to achieve seawater desalination. At the same time, this phase integrates knowledge from geography to analyse the overview of marine resources, from biology to explore the necessity of freshwater resources to sustain living organisms, and from political science to explore the strategic significance of marine resource development, forming an interdisciplinary knowledge network (Michael et al., 2025).

Lesson 2: Technological interventions, bridging technology and science, introduction of flash evaporation and membrane separation technologies, and clarification of the "scientific knowledge → technological application" pathway. Students will work in small groups to select an island or an archipelago and present the reasons for their choice (significance, value), analyse the size of the island, its resources, its population, the equipment and methods available for obtaining fresh water, and so on. Then introduce the method of freshwater extraction that the group will choose: flash evaporation or membrane separation technology; combine evaporation and filtration experiments, understand the principles of flash evaporation and membrane separation technology, and analyse the feasibility and efficiency of freshwater extraction based on mathematical models. The teacher organism a group-based evaluation and improvement of the group and other reporting groups.

The core objective is to guide students to analyse the technical principles and apply interdisciplinary knowledge to complete a scientific and feasible practical design plan, and to cultivate students' innovative thinking, practical ability, quantitative analysis ability and teamwork ability. At the same time, this phase systematically analyses the feasibility of seawater desalination in view of the scarcity of freshwater resources in the geographic island environment. Through the cross-application of multidisciplinary knowledge, we can not only analyse the process of material separation and energy conversion, but also evaluate the efficiency and sustainability of the technology implementation under the resource constraints of the island, so as to provide scientific and quantitative solutions to the problem of freshwater resources acquisition on the island.

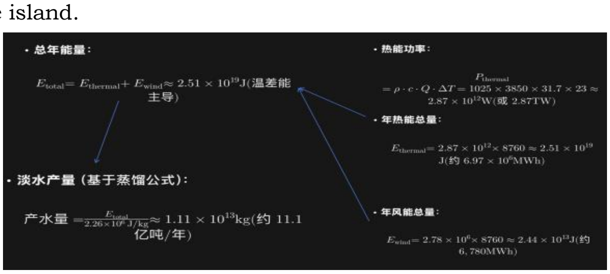

Figure1. Mathematical modelling quantitative analysis

Lesson 3: System Integration, digging deeper and developing engineering thinking and quantitative analysis skills, incorporating mathematical efficiency formulas and multi-dimensional assessments. System design, further improve the project proposal from the perspectives of cost, environment, policies and regulations, quantitative, and design a model to demonstrate the results (Makonye Judah P. & Moodley Nageshwari Pama, 2023).

The core objectives are to further improve the programme from the perspectives of cost, environment, policies and regulations, and quantitative; and to explore students' engineering thinking and quantitative analysis ability. At the same time, the integrated application of multiple disciplines, combined with political policies and the significance of resource development to cultivate students' social decision-making ability, awareness of resource Mutilation as well as innovative thinking.

Figure 2. Resource utilization model design

2.4. Developing evaluation strategies and constructing evaluation scales

The Chemistry Curriculum Standard 2022 states that evaluation is an important and indispensable part of the teaching system, and its main function is to diagnose the learning effect, improve teaching and promote the implementation of the curriculum objectives. It establishes a scientific view of evaluation, adheres to core literacy-oriented evaluation, strengthens process evaluation, improves assumptive evaluation, deepens comprehensive evaluation and explores value-added evaluation, and promotes students' all-round and interpersonal development. This interdisciplinary teaching establishes a multi-dimensional evaluation system with three dimensions: infra-group mutual evaluation, inter-group evaluation and expressive evaluation. The infra-group mutual evaluation can help detect imbalance in task distribution and loopholes in details, effectively enhance students' internal motivation to learn, and encourage students to supervise each other and share the work (Xiaotong Li, 2024). Inter-group evaluation can stimulate students' sense of competition and enhance their motivation to participate, and at the same time, inter- group evaluation can also help each other identify problems, facilitate timely solutions and improve the programme, and provide a reference for cross-team experience and strategy adjustment. Teachers integrating STEM education use expressive evaluation as a means of curriculum evaluation, focusing on both the process of student participation and performance during the project, as well as the evaluation of learning outcomes such as artefacts and project solutions after the completion of the project. Teachers, as guides, have sufficient teaching experience and can accurately identify problems and defects in the process of students' project implementation, so the expressive evaluation made by teachers in response to students' performance can comprehensively control the quality and feasibility of students' project solutions. The multidimensional and multi-subjective evaluation mechanism can effectively avoid the subjective bias of a single theme, reflect the real phenomenon more comprehensively, and help to identify problems in time to optimise the programme.

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Table 1. "Comprehensive Mutilation of Marine Resources" Project Evaluation Table

		Level 1	Level 2	Level 3
Scientific Concepts	Principles of evaporation (distillation)	Cannot understand the basic principles of evaporation.	Can understand that the macroscopic reason for evaporation is based on different boiling points	Based on the core knowledge of subjects such as physics and chemistry, grasp the principle of evaporation is based on different states and separating gases from other states of matter.
	Principles of Filtration, Membrane Separation	Cannot understand the basic principles of filtration.	Can understand the macroscopic reasons for filtration as separating solids from liquids based on different states.	Understand the similarities between filtration and membrane separation techniques based on the microscopic perspective of separating different substances based on particle size.
Scientific Thinking	Integrating Science and Technology, Engineering Thinking	Analyse existing methods such as flash evaporation and membrane separation techniques without a clear perspective or focusing on a single discipline and ignoring the technology.	When analysing existing methods, such as flash evaporation and membrane separation technology, the concepts and the technology behind the interdisciplinary concepts are focused on for a more rational explanation.	When analysing existing methods such as flash evaporation and membrane separation technology, focus on interdisciplinary concepts and the technology behind them, provide reasonable explanations, pay attention to the actual situation and needs of the island, and analyse the project as a whole.
Scientific Research and Practice	Comprehensive Mutilation of Resources	No awareness of resources, no concern for the use of marine resources;	Concerned about marine resources, adopting a certain marine resource as an energy source for fresh water acquisition technology;	Awareness of the importance of resources, taking the initiative to analyse the current situation of marine power resources and mineral resources, and making comprehensive use of them.
Scientific Attitude	Ability to acquire information, ability to work in a team	Weak sense of participation, little communication and expression;	To a certain extent exerting their own wisdom and ability, actively accessing information, partially participating in expression;	Effective screening of useful information, good at communication and expression, playing a leadership role, able to co-ordinate and organise from many sides in the team.

3. project-based STEM teaching implementation strategies

3.1. Based on the curriculum standard association, mining interdisciplinary themes

Based on the national curriculum standards, we look for teaching contents that are suitable for multiple disciplines, as well as common parenting goals, to avoid disciplinary patchwork. By analysis the different perspectives of each discipline on the same theme, design theme anchors to achieve natural integration of knowledge. We integrate interdisciplinary knowledge by combining "horizontal analysis + vertical correlation" of the standards of various disciplines, so as to break down complex technologies into comprehensible disciplinary principles and form a knowledge chain (Puška Edisa & Puška Adis, 2022).

3.2. Build immersive project learning scenarios driven by real projects

The project is designed around solving real problems, so that students can learn by doing. Students will experience the process of selecting islands and reefs based on the information they have and the cognitive level of the students, analyzing resources and designing technical solutions together as a group, and then the teacher will assist the students in assessing the feasibility of the project, and then optimize the project by combining the political, military, ecological and other dimensions, so as to realize the leap from the cultivation of the students' ability to apply knowledge in interdisciplinary subjects to the ability to solve complex problems.

3.3. Innovation and demonstration

Break the traditional mode of teaching scientific knowledge and technology application, through the scientific principles of technology intervention on the basis of the construction of the engineering system of this trinity of teaching processes, so that students understand that scientific knowledge is the basis of technological development, technology is a tool for engineering development, and ultimately to achieve the goal of the use of engineering. Using the method of embedding technology cases and infiltrating engineering thinking, students are guided to evaluate the programme from the perspectives of technical feasibility, cost-effectiveness, environmental impact, etc., so as to cultivate their engineering thinking and comprehensive ability. Mathematical modelling and data analysis are integrated into the STEM project to enhance the rigour of thinking and students' quantitative analysis ability through quantitative assessment. For example, students independently developed a formula for calculating freshwater efficiency and compared the water production per unit of energy consumption of different technologies all reflecting the fact that students' quantitative analytical ability and engineering thinking can be enhanced through teachers' guidance and teaching.

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