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Analysis of Offering a Special Marine Environmental Engineering Curriculum in Marine Majors Based on Coordinated Land and Marine Development Conception

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Abstract: *Using engineering technology to mitigate marine environmental deterioration can promote marine sustainable development. College education of marine environmental engineering (MEE) is key to culture professionals of social needs. Although marine colleges generally recognize the importance of MEE, public availably specialized teaching materials are insufficient. The cultivation of component talents with knowledge of marine resource development and environmental protection is weakened. To enrich marine higher marine education, based on the comprehensive analysis of history literatures, the study discussed definition, and teaching content scope of MEE. Lastly, a primary course content framework of MEE was built. The framework will provide a reference for the teaching practice of marine resources and environment related majors.*

Keywords: *Marine Environmental Conservation, Higher Education, Marine Engineering, Sustainable Development*

1. Introduction

The ocean covers approximately 71% surface area of the earth. Marine is the second space for human development. Global population growth accelerates the human exploitation of the marine. To alleviate human-land conflicts, some developing countries, such as China, has been implementing a higher level national marine development strategy. Both the 19th and 20th National Congress of the Communist Party of China emphasized the importance of marine development. Under the global background of sustainable development, the marine exploitation must be coordinated with environmental protection [1]. Ensuring the health of the ecology while developing and utilizing marine resources has become a basic policy.

Nowadays, economic development cannot be at the expense of the environment. Marine development is higher technically challenging. The world needs more compound professionals with knowledge of marine resources exploitation and environmental protection. China has established ten ocean universities. Additionally, more secondary colleges have set up marine related majors, such as 36 higher schools offering marine science majors alone (https://www.gaokao.cn/special/130?special_type=3). The university's marine majors have covered science, engineering, agronomy and medicine. Professional education of marine-related majors is developing rapidly.

The cultivation of professional talents is closely related to the setting of professional curriculums. Traditional resource exploitation-related disciplines, such as petroleum, vessel, and biology, having relatively more solid foundations. However, marine environmental curriculum struggles to maintain a place in school [2]. Marine environment research is widely and persistently concerned (more than 86, 000 results were found via searching marine environment topic in SCI & SSCI database in Web of Science). Insufficient marine environmental curriculum is inconsistent with their quick research development. It is necessary to summarize the knowledge related to marine environmental science, conduct more course teaching researches, and furtherly promote the development of marine professional education.

The past marine environmental science mainly focused on explaining natural mechanisms, human disturbance effects, and environmental risk [3]. In other words, past curriculums were inclined to impart knowledge of environmental science or ecological science. The technical content of environmental

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repairing is relatively lacking. Although the course theory of environmental engineering is relatively systematic and sound, it mainly addresses terrestrial environmental problems.

Being connected to the land, the root of many marine environmental problems lies on the land. Based on the coordinated land and marine development framework, this paper comprehensively analyzed past teaching researches of marine environmental science, ecological science, and environmental engineering science. Lastly, a relatively more concise teaching content system framework for marine environmental engineering (MEE) courses has been proposed.

2. Materials and Methods

To analyze MEE curriculum offering, the study retrieved information of ocean universities and majors in a popular college entrance examination information network (https://www.gaokao.cn/) and university ranking network (https://www.shanghairanking.cn/). Official website of ocean universities or colleges having marine-related majors were collected and integrated into an institute list. Considering MEE is an engineering discipline, majors of marine resource exploitation, environmental engineering in ocean university, and marine resource and environment were especially concerned. Course outlines and professional training programs was collected. Furtherly, marine environment related content scopes were extracted to form a table.

To analyze definition of MEE, narratives of marine environmental science, and marine restoration were extracted from history textbooks of large publishers (e.g., Higher Education Press). Additionally, authoritatively international environmental institute released governance action plans (e.g., United Nations) were collected to analyze teaching content of MEE.

With the goal of solving the major environmental problems, after a full content analysis of history literatures, the framework of MEE was proposed based on the coordinated land-marine development conception.

3. Results and Discussions

3.1 Analysis of Curriculum Offerings of Marine Environmental Engineering

Based on the public available data (Table 1), it was found that ocean-related universities/colleges generally recognized the importance of setting up curriculum of marine environmental engineering. The course knowledge scope covered principles of environmental engineering, ship and port pollution control, and pollution control and remediation of coastal zone and seawater. However, approximately a half of the colleges did not set up special MEE. Two to three different courses covering different aspects were offered to college student. Additionally, publicly available teaching materials were scare, especially special textbook of MEE. Although more courses can provide more information, the knowledge systematization will deteriorate. Due to the need for teachers to invest more energy and require more teachers, increasing the human resource burdens of institutions.

3.2 Analysis of Curriculum Knowledge System

3.2.1 Major Marine Environmental Problems that Need to be Addressed

Urban expansion caused shrinking and degradation of natural habitat, such as mangrove, coral reef, and seagrass bed [4]. Marine fish stocks are declining, some coastal regions are depleted. Biodiversity loss is a big challenge for marine environmental protection. Additionally, global warming, ocean warming, sea level rise, and ocean acidification (another problem of CO_2) was triggered by excess greenhouse gas emissions from human industrial production and everyday living [5]. A large number of biogenic elements, such as nitrogen, and phosphorus, has been discharging into the sea. The surplus nutrients lead to eutrophication and hypoxia in water bodies. Ecological disasters, such as red tides, brown tides, and green tides, often occur in coastal estuaries and bays [6]. Persistent pollutants (e.g., heavy metals, petroleum pollution) were transferred and accumulated in higher trophic marine organisms [7]. Otherwise, microplastics (wasted plastics with diameter less than 5 mm) were ubiquitously detected in marine environment, threatening healthy of wild animals and human food safety [8]. There are many human-caused marine environmental problems. At least, the MEE should focus on solving above-mentioned major marine environmental problems.

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3.2.2 Definition of Marine Environmental Engineering

A relatively clear curriculum teaching objective of MEE was described on the official website of Ocean University of China (http://cese.ouc.edu.cn/2018/0418/c6231a188018/page.psp). Through the study of this course, students are expected to understand the existing marine environmental pollution problems and countermeasures, and have the ability to use the existing basic knowledge of environmental engineering to analyze marine environmental problems and propose solutions. Comparison analysis (Table 2) of marine environmental-related definition displayed that MEE should focus on professional knowledge of pollution control, and human disturbed-environment remediation. Due the complexity of nature ecology and widely interaction with human activities, the human governance should improve the self-healing capacity of the nature [9].

Table 1: Curriculum offerings of marine environmental engineering (MEE) in ocean-related universities/colleges in China

NO.	Major	Special MEE	Teaching Scope		
			Environmental Engineering	Ship and Port Pollution Control	Pollution Control and Remediation of Coastal Zone and Seawater
1	Marine Resource Exploitation Technology	No	NA	NA	NA
2		Yes	NA	NA	Yes
3		Yes	NA	NA	Yes
4		Yes	NA	NA	Yes
5		Yes	NA	NA	NA
6		No	NA	NA	NA
7		Yes	NA	NA	NA
8		No	NA	NA	NA
9		No	NA	NA	NA
10		Yes	Yes	Yes	Yes
11	Marine Environmental Engineering	Yes	Yes	Yes	Yes
12	Environmental Engineering	No	Yes	Yes	Yes
13		No	Yes	Yes	Yes
14		No	Yes	NA	NA
15		No	Yes	NA	NA
16		No	Yes	NA	NA
17		No	Yes	NA	NA
18	Marine Science	Yes	Yes	Yes	Yes
19	Marine Chemistry	Yes	NA	NA	NA
20	Environmental Science	No	Yes	NA	NA

Notice: NA-not available

The root of marine environmental problems lies heavily in human activities on land [10]. International society proposed a “source - to - sea approach” (Figure 1) as a new form of marine environment management [7]. The integrated environmental governance takes all physiographic regions (e.g., rivers) from which substances enter the sea into consideration. The interconnection of land and sea was valued. Besides endpoint remediation, source pollution control is also an important aspect. In the new era, the thinking of coordinated land-sea development should be integrated into knowledge system of MEE. Besides estuary, bay, and the open ocean, MEE should cover land regions closely linked to the sea, such as rivers flowing to the sea, and coastal zones.

In summary, MEE mainly takes human disturbed sea regions and sea closely linked land regions as objects, based on the conception of coordinated land and marine development, teaching professional knowledges of pollution control and remediation to solve major marine environmental problems.

3.2.3 Analysis of Professional Knowledge Scope of Marine Environmental Engineering

MEE is an engineering technology subject, mainly focus on summarizing professional knowledge of environmental or ecological principles and measures to solve major marine environmental problems. MEE is oriented towards environmental problems. It is worth noting that natural marine environment is very different from human environment. Environmental treatment is facing a larger volume and area with higher uncertainty. For example, industrial waste water can be collected pipelines to be purified in plant,

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but the polluted bay water is too large to be treated in the same way. Sometimes, ecological methods are applied to repair in situ.

Aiming at the problem of water eutrophication in coastal rivers, estuaries, and nearshore, MEE can summarize knowledge to explain the methods of ecological restoration of water body and sediment, such as ecological floating flat, constructed wetland, etc. [9]. To carry out conception of coordinated land-sea development, section of water purification in traditional environmental engineering course can also be introduced to student. For example, ecological restoration technology of river and estuary can be introduced. The principle of waste water purification in land plant can inspire college student to figure out new methods to solve seawater pollution [11]. Additionally, the knowledge of marine assimilative capacity, and total amount control of pollution emission can be integrated to explain source governance [12].

Control knowledge of ecological disaster (e.g., harmful algae blooms [e.g., red tide, green tide], hypoxia, coastal erosion) is an important part of MEE. After introducing the basic principle of rapid growth of algae growth, possible treatments, such as using clay spreading, mechanical salvage of Enteromorpha, can be integrated into the course [13]. Based on the pollution source control, greener production can also be introduced, such as polyculture of fish and algae. In recent years, ecological friendly seawall as an altering method of preventing coastal erosion is developing quickly around the world [14]. The engineering construction of green seawall can be integrated into knowledge system of MEE.

Table 2: Definitions of mare environmental science and engineering

Terms	Definitions	Literatures
Marine Environment	The totality of various ocean factors that affect human survival and development, including natural ocean factors and artificially modified ocean factors	[18]
Marine Environment	The environment in which organisms live under the influence of human activities includes the natural environment under human influence (such as polluted environment, degraded environment, etc.). The totality of the physical, chemical, geological and biological environment in all natural environments surrounding living things under human influence	[19]
Marine Environmental Protection	Utilize the theories and methods of modern environmental science and marine environmental science to coordinate the relationship between human beings and marine ecology, and solve various marine environmental problems. It is the general term for all human activities to protect, improve and create a sustainable marine environment.	[20]
Marine Environmental Science	Comprehensively apply the knowledge of various branches of marine science, study the changes in the marine environment caused by human activities and their impact, and combine social, legal, and economic factors to implement a comprehensive discipline that protects the marine environment and its resources.	
Marine Ecological Remediation	On the basis of giving full play to the self-repair function of the marine ecosystem, necessary artificial means such as appropriate engineering or non-engineering measures are taken to promote the restoration of the damaged marine ecosystem to a sustainable natural, healthy, stable and self-sustaining state. It is a marine ecological environmental protection action that improves the integrity and sustainability of its ecosystem and ultimately restores its service functions.	[21]
Marine Restoration Ecology	It is an emerging discipline that studies the causes and processes of marine ecosystem degradation, as well as the theory and technology of evaluation, restoration and management of degraded ecosystems, including habitat restoration, biological restoration, ecosystem restoration and ecological landscape restoration	[13]

Remediation of persistent chemical pollution is suggested to be a knowledge part of MEE. Lots of persistent pollutants (e.g., heavy metals, petroleum) ended in the sea water or sediment via runoffs, atmospheric settlements, or accidently leakage, threating higher trophic marine organisms by food chain biomagnification [7]. Diverse remediation methods have been developed, such as physicochemical,

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biological, and bio-electrochemical processes [15]. The salt-resistant plants or macro-algae can be planted in polluted beach or seawater region to absorb heavy metals [13]. Marine bacterium plays an important role in removing toxins [16]. To cope with harmful petroleum leakage, emergency management measures can be introduced [17], such as sea fence, oil-absorbing felt [13]. Besides chemical removal technologies, other social and economic measures (e.g., cleaner production, garbage classification) is usually needed to repair a polluted sea zone. The integrated control process can be introduced in this section of MEE.

To mitigate declining of fish stocks, biodiversity loss, and habitat degradation, MEE can introduce measures of biological resource conservation (e.g., fishery artificial breeding and release, artificial reef, and construction of ecological marine ranch), artificial mangrove planting, restoration of seagrass bed, and coral reef remediation [21]. Additionally, beach restoration is another important aspect. For example, structure design of artificial sand filling and wave breaker building can be introduced to student. Greener coastal constructions have been developed, such as installation of a fence to trap sand for salt-tolerance plant growing. The yearly expanding grass plays roles on intercepting more sand around the root area, the sand beach was naturally repaired [9].

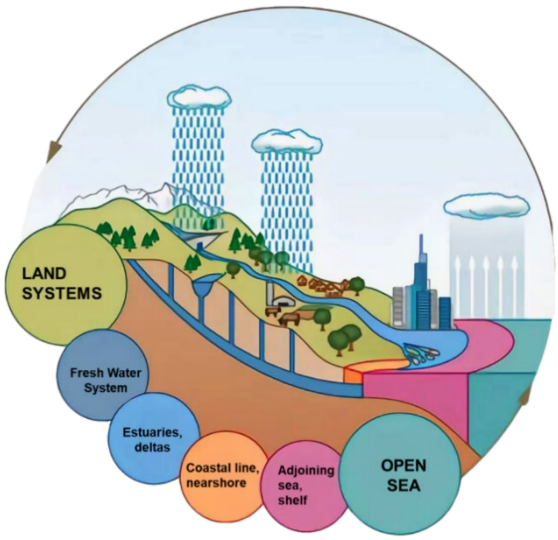

Figure 1: The new environmental governance idea of "source - to - sea approach" [7].

The problem of marine solid waste pollution, especially plastic pollution, has received great attention from the international community in recent years. In 2023, the theme of World Environment Day is "Beat Plastic Pollution". The United Nations have released two action plans: Turning off the Tap: How the world can end plastic pollution and create a circular economy, and Addressing Marine Plastics: A Systemic Approach – Recommendations for Actions. Using Fishing boats to salvage marine debris was tried in some regions. Otherwise, new methods, such as algae adsorption, membrane technology, etc., were tried to remove microplastics from environment [22]. The social governance and removal technology of marine plastics can be integrated into MEE course.

Marine is not only a receiving station for pollutants, but also actively eliminates human influence. On the one hand, pretreated sewage sometimes be delivered to offshore zone for natural purification [18]. Prerequisites and basic structures of sea drainage project can be introduced in MEE. On the other hand, due to the profound influences of GHGs (green-house gasses) caused global climate change forced the world to find solutions. Marine have attracted more attentions for its capacity of carbon sink. In China, scientists headed by academician Nianzhi Jiao proposed to apply carbon fixation principles of biological pump (photosynthetic algae and zooplankton convert atmospheric CO_2 into particulate organic carbon (POC) and sink to the seabed), microbial carbon pump (marine micro-organisms are major contributors to inert organic carbon), and carbonate carbon pump (microorganisms induced carbonate precipitation) to develop environmental technologies of ocean negative carbon emission (ONCE). MEE can track and introduce knowledge of ONCE-related research progress [23]. Ocean iron and aluminum fertilization experiments has been carried out for increasing carbon fixation in sea region having less microorganisms. To mitigate ocean acidification, researches tried to use alkaline powder (e.g., lime) to neutralize the lowered acidity [24]. Green mineral crystals are also tried to be added to the sea beach to resistant acidity [25]. Alkaline seawater has the ability to absorb more carbon dioxide.

To improve students' innovative thinking and practical ability, the experimental course of MEE can

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be set up based on the combination of classroom experiments and field visits. In reality, construction of environmental engineering often needs large quantities and long periods. It is very hard to be complete in a very limit time. Classroom teaching of experiment can be mainly composed of traditional sewage purification, such as activated charcoal absorption, and coagulation experiment. Field visits of sewage treatment plant, constructed green seawall, and conservation area of mangrove, coral reef etc., can be used to strengthen student's understanding of large marine environmental engineering.

4. Conclusions

Due to the requirement of sustainable marine development, lots of marine-related universities or colleges are taking efforts to teach MEE-related curriculums for student. Although the researches of marine environmental science are developing quickly, analysis of MEE-related teaching is insufficient. Due to the difficult of public availably special teaching literatures, multiple subjects are usually needed to teach knowledge of MEE in colleges. Based on a comprehensive analysis, this study found that professional knowledge of MEE can be integrated via the conception of coordinated land-sea development. Marine-related knowledge from traditional environmental engineering (e.g., sewage purification), remediation of persistent chemical toxins (e.g., heavy metals), ecologically constructed wetland and seawall, ecological restoration of coastal habitats (e.g., mangrove, coral reef), governance of wasted plastics, and recently developed technologies of ocean negative carbon emission and adding antacids to the ocean can be integrated into the course content of MEE. The experiment course can be combined by classroom teaching of water purification and field visit of sewage treatment plants, ecological constructed engineering, and marine conservation institutes. To concentrate scattered knowledge, a special textbook of MEE is suggested to be edited in the future. The proposed professional knowledge framework will help marine-related colleges improve teach quality and efficiency for MEE.

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