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Research to improve maritime education and training for energy efficient ship operation in China

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RESEARCH TO IMPROVE MARITIME EDUCATION AND TRAINING FOR ENERGY EFFICIENT SHIP OPERATION IN CHINA

By

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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(Date): 17th September, 2018

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Abstract

Title of Dissertation: **Research to Improve Maritime Education and Training for Energy Efficient Ship Operation in China**

Degree: **Master of Science**

The dissertation is a study to improve Chinese maritime education and training (MET) for raising the performance of energy efficient ship operation, by analyzing the increasing demand on seafarers' capacity and the barriers existing in the Chinese MET for energy efficient ship operation. Finally, a systematic framework of improvement measures was provided for Chinese MET.

A brief review of the increasing demand on seafarers for energy efficient ship operation was carried out from four aspects including regulations, practices on board ships, alternative fuel and renewable energy sources. Based on the increasing demand, the barriers existing in the Chinese MET was analyzed by literature review and questionnaires. The final presentation of the barriers was obtained by an online workshop, the barriers include four aspects, courses, pedagogy, cognition practice, and cultural construction. Additionally, each aspect of the barriers includes four dimensions, which are human resource, financial resource, other resource and policy. Furthermore, in order to develop the framework of improvement measures, the lessons from other industries were also analyzed by literature review.

On the basis of the increasing demand on seafarers and the identified barriers, a systematic framework of improvement measures was built up, which contains two new subjects, a comprehensive project for improving pedagogy, and some recommendations for cognition practice, cultural construction and policy making.

Additionally, a batch of cognition practice of Marine Engineering students of DMU was chosen to assess the advised workshop through online communication with educators. All attending students believed that the workshop is helpful for improving understanding of energy efficient ship operation. Finally, the PDCA cycle and the participatory design approach were introduced for the development of the framework.

KEYWORDS: Energy Efficient Ship Operation, Maritime Education and Training, China, Barriers, Demand, Improvement Measures

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List of Abbreviations

BIMCO	Baltic and International Maritime Council
DCS	Data Collection System
DNV GL	Det Norske Veritas Germanischer Lloyd
EC	European Commission
ECDIS	Electronic Chart Display and Information System
EEDI	Energy Efficiency Design Index
EEOI	Energy Efficiency Operational Indicator
EU	European Union
GHG	Greenhouse Gas
GRT	Gross Tonnage
ICS	International Chamber of Shipping
IMO	International Maritime Organization
ISO	International Standards Organization
LNG	Liquefied Natural Gas
MARPOL	The International Convention for the Prevention of Pollution From Ships
MEPC	Marine Environmental Protection Committee
SEEMP	Ship Energy Efficiency Management Plan
STCW	International convention on Standard of Training, Certification and Watch keeping
US	United States

1. Introduction

The international shipping industry consists of a significant part of the global economy. At present, almost 80% of world trade in goods is transported by international shipping industry (ECSA, 2017). The International Maritime Organization (IMO) reported that over the past 40 years, international shipping trade has increased by 500% (Chang, 2012). With the booming of shipping industry, however, a number of air pollutants and emissions of greenhouse gas (GHG) have been brought into the atmosphere. During the year 2012, 796 million tones CO_2 and 816 million tones other GHGs were from international shipping (IMO, 2015).

The elements of GHGs from shipping are, for example, carbon dioxide (CO_2), methane (CH_4) and nitrogen oxide (N_2O). CO_2 is the main factor of global warming trend. In addition, there are other gases emitted by ships impacting climate, such as black carbon with a warming effect, and sulphate particles with a cooling effect. These pollutants contribute to global climate change directly, which can act as agents that restore heat in the atmosphere, or promote the generation of other GHGs. The more GHGs are emitted, the warmer the Earth will become. The warmer Earth has caused a series of catastrophic results across the globe, for instance worse droughts, stronger storms, flooding, extinction of species, and disruption of food (Corbett et al, 2007). The oceans are also becoming more acidic with the increasing amount of carbon dioxide absorbed. Future coral reefs and other organisms, which are applied to produce calcium carbonate shells and skeletons, are being impacted. Then a number of important marine food webs could be broken down, some of which are essential for human beings (Feely et al, 2004).

To address these issues, the IMO has adopted several guidelines for improving energy efficiency by the Energy Efficiency Design Index (EEDI), the Ship Energy Efficiency Management Plan (SEEMP), the Energy Efficiency Operational Indicator (EEOI) and the Data Collection System (DCS) (IMO, 2017a). The guidelines mainly focus on both the ship design phase and the ship operation phase. Additionally, The EEDI and SEEMP are mandatory as amendments to MARPOL Annex VI, which apply to vessels exceeding 400 GRT, the DCS is for ships of 5,000 gross tonnage and above.

Although a number of technical and operational measures have been introduced into the shipping industry to improve energy efficiency of ships, are they sufficient? Considering the fact that population growth and subsequent economic development are expected, further severe measures should be taken to lower emissions from ships. According to the DNV GL Energy management study, the lack of education and training is the primary barrier for improving the energy efficient ships operation (DNV GL, 2015). Indeed, energy efficient measures are implemented by educated and trained seafarers who operate ships. Satisfactory knowledge and pertinent training should be equipped for the operators, for example, weight distributions and expertise on the optimization software for the trim optimization.

Therefore, in order to achieve the effective implementation of the technical and operational measures on ships, and improve the energy performance of ship operation, there is an urgent need to update maritime education and training (MET) by reflecting the need of energy efficient ship operation.

1.1 Background

In order to further enhance safe, secure, and efficient shipping on clean oceans through education, research, and capacity building, the World Maritime University (WMU) was founded in 1983 by the IMO, which is a specialized agency of the United Nations. In 2016, the WMU established a new Master program called the Maritime Energy Management (MEM), which offers a unique, holistic nature of academic program in the world by now. The MEM is designed for people with technical and other backgrounds, such as ship operators, administrators, port and shipyard managers and professionals and so on. This specialization focuses on capacity building for developing and developed countries by providing a comprehensive understanding of different aspects of maritime energy management with a vision towards achieving a sustainable, energy efficient and low carbon maritime industry.

Furthermore, with the concept of energy efficient shipping emerging from the water, research in MET have been carried out to improve energy efficiency of shipping all over the world. Some of research results are indicated as follows:

Swe, Kitada, and Ölçer (2018) discussed how Myanmar can approach energy efficient shipping through MET. This research identified four aspects to focus on maritime energy management in Myanmar, for instance Legislation; Research collaboration and dissemination; IMO model course; and Regional cooperation.

Jensen, Lützen, Mikkelsen, Rasmussen, Pedersen and Schamby (2017) conducted simulator tests including human factors and technical issues. The test sessions consisted of a combination of practical simulator exercises and reflection workshops. The results show that during the exercises the officers can find a suitable trade-off between safety and energy efficiency of ships. On average, about 10% fuel can be saved.

According to Acikgoz (2011), it is necessary to raise environmental sensitization of the younger generation for sustainable development. A well-designed educational course about energy is very important for developing innovative approaches to address environmental problems. The introduction of secondary education system to renewable energy advancements has shown that students are well-known for a number of renewable technologies (Champion, Greene, Morrissey & Postawko, 2014; Kandpal & Broman, 2014).

According to Kitada & Ölçer (2015), human intervention is very important for energy efficiency achieved in term of selecting and implementing related technical and operational measures for ships. Particularly, when facing implementation, operators should be equipped with sufficient knowledge and well training for the measures selected. For example, if slow steaming is selected to be carried out for the ship, operators needs to know the characteristics of main engine and have expertise on the related software. Therefore, education and training for the energy efficiency measures are the key area for energy efficient ship operations.

In conclusion, the WMU is the leader of MET for international shipping all over the world. The best practices of WMU and other research results should be analyzed and introduced for the MET in order to respond to a rapid transformation need of MET for energy efficient shipping. To explore the role of MET in the shipping industry, it is also worth looking into the trends and challenges in non-maritime sectors. Hence, the following sections will review lessons from selected industries dominant in China.

1.2 Problem statement

China is estimated to be the largest seafarer supply country (BIMCO & ICS, 2016). As of end of 2016, the total number of seafarers registered with MSA China stands at 1,392,751. At present, over 10 universities provide degree cadets, for instance DMU (Dalian Maritime University), SMU (Shanghai Maritime University), JMU (Jimei University), and WUT (Wuhan University of Technology). Over 30 colleges provide diploma cadets, and over 100 over training centers provide STCW training programs.

From 2012, China started to consider the maritime education focusing on international regulations and new technologies for energy efficient shipping. For example, in DMU some general introduction for MARPOL convention and advanced technologies such as air lubrication, design of bulbous bow and hull, and renewable energy were added into the course of MARINE ENGINEERING MANAGEMENT in September 2012.

However, there is no systematic approach in an MET program for energy efficient ship operation in China by now. Students can only obtain some fragmented knowledge on energy efficient ship operation, which would limit their capacity of implementing energy efficient ship operation. As a result, after they graduate, it is very difficult to fit the requirements of energy efficient ship operation. In addition, MET curriculum are supposed to be designed along with the development of the shipping industry, or even ahead of the current requirements of shipping industry. Because training seafarers takes 2-4 years, and they are the core actor of the shipping industry, their role is crucial; they are the ones who finally implement each energy efficient measure on board. Therefore, there is an urgent need to develop a systematic approach to improve MET of China for energy efficient ship operation.

1.3 Objectives and Research Questions

At present, the performance of energy efficient ship operation is not satisfactory, and there is scarcely any research on Chinese MET for energy efficient shipping. In order to improve Chinese MET for raising the performance of energy efficient ship operation, this research aims for reviewing the increasing demand on seafarers' capacity and analyzing MET-related barriers in terms of energy efficient ship operation Furthermore, the research also proposes a framework of improvement measures for Chinese MET to support energy efficient ship operation. The following research questions will be answered:

- How does the development of energy efficiency measures impose an increasing demand on seafarers' capacity for energy efficient ship operation at an international level?
- What is the present situation of MET of China for energy efficient ship operation?
- What are the barriers existing in Chinese MET to achieve energy efficient

ship operation?; and

- How can Chinese MET adopt a systematic and continually improved approach to improve for energy efficient ship operation?

1.4 Methodology

This study is carried out by literature review, qualitative analysis, questionnaires, and online workshop. The details are shown as follows:

1.4.1 Reviewing the increasing demand on seafarers' capacity for energy efficient ship operation

The demand on seafarers' capacity with the development of international shipping is identified by analyzing the existing technical and operational measures for energy efficiency and the trend of new technologies and equipment at international, regional and national levels.

1.4.2 Identifying and categorizing barriers

The gaps existing in MET in China relating to implementation of energy efficiency will be identified and categorized. A thorough literature review will be conducted. As there is limited literature on the gaps in MET, the accumulated knowledge and experience from teachers, seafarers, managers of MET, shipping companies and other industrial sectors will be taken into consideration for analysis. The gathered data is basis on literatures, questionnaires and online workshops performed by 11 educators including 2 managers, based in China. The educators are required to have at least 10 years' experience of education and training, and be the experienced Chief Engineer or Captain. The managers are required to have at least 10-year experience in the management of MET.

The barriers are going to be defined from several aspects, such as the content of courses, cognition practice of ships, capacity of teachers or trainers, pedagogy, cultural construction for energy efficient ships operation, and MET policy.

1.4.3 Analyzing the barriers and determining their criticality in MET

Since several barriers in Chinese MET may hinder the uptake of some measures and various stakeholders in Chinese MET may have conflicting objectives, it may be difficult to prioritize and identify barriers which are more critical or beneficial to overcome in Chinese MET.

1.4.4 Building up a framework of improvement measures for overcoming the barriers in MET

Once the barriers are identified, some improvement measures would be analyzed to overcome the barriers. The measures cover key content of the barriers and Chinese MET.

The framework of improvement measures is the main output of this research, which is based on the results of workshop, questionnaires and literature review. The following steps will be taken to identify the key aspects for the framework.

1.4.5 Assessment and continual Improvement

A ship cognition field study of Marine Engineering students in Dalian Maritime University (DMU) will be chosen for assessing whether the preliminary results can be validated through online communication with trainers. During a ship cognition field study in DMU, around 90 students have theory and practice courses on the training vessel (YUKUN vessel) for one month.

Continual improvement is significant for sustainably improving Chinese MET along with the development of international shipping. Therefore, an iterative loop will be formed that leads to the continuous improvement in MET. In addition, the Plan-Do-Check-Act (PDCA) cycle and participatory design approach are employed for continually improving the framework of improvement measures. The research roadmap for improving MET for energy efficient ships operation in China as follows:

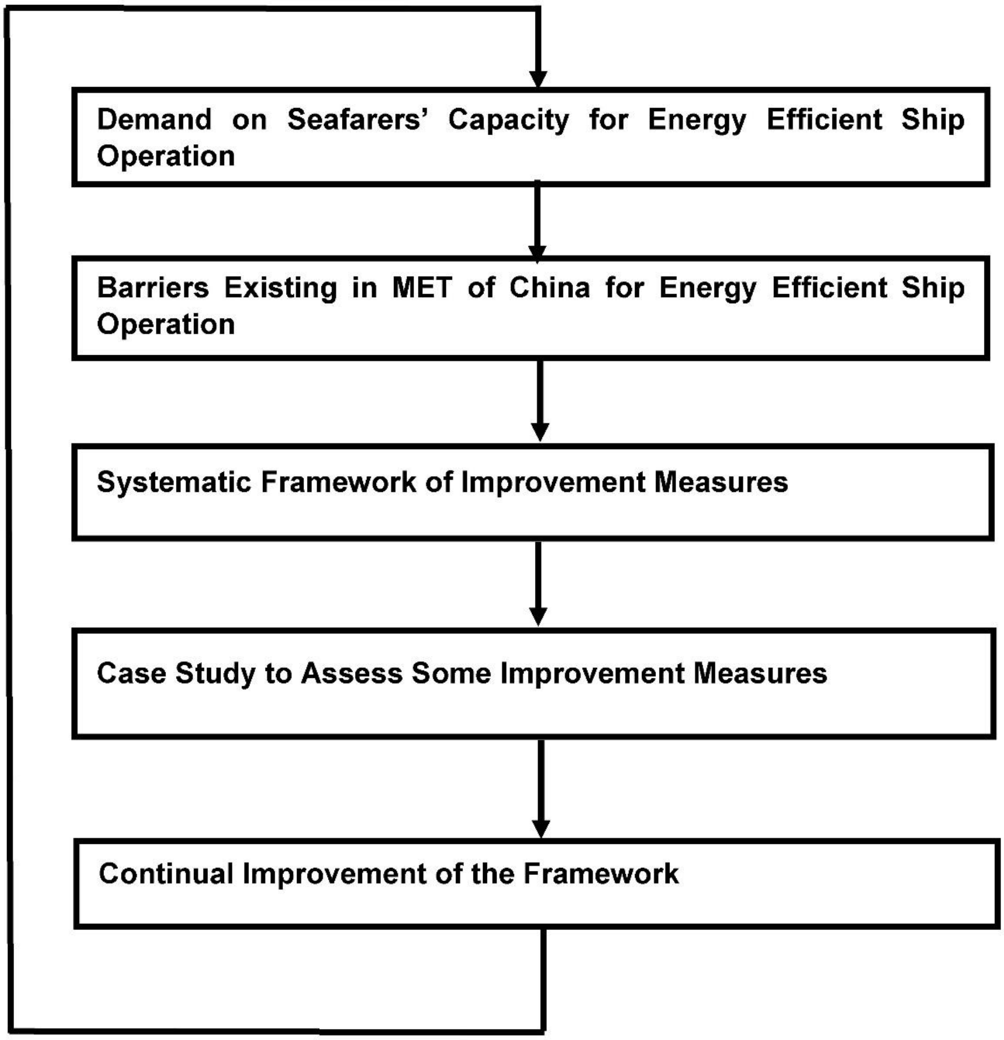

Figure 1: The research roadmap for improving MET for energy efficient ships operation in China

(Source: Author)

1.5 Limitations

The collected data is mainly from China, and the approved framework is mainly available for undergraduate education in China with some reference value for vocational education in China.

Certain data were restricted in respect of data protection policies of the private companies consulted; hence it becomes part of the limitations of this study.

1.6 Structure of study

The demand to seafarers' capacity is increasing with the development of energy efficiency measures, therefore this study starts with the analysis of energy efficiency measures to define the increasing demand to seafarers' capacity for energy efficient ship operation at an international level. The increasing demand for seafarers is the main driver for improving MET. Hence, the barriers existing in the MET of China for energy efficient ship operation are identified by literature review, questionnaires and online workshop based on the defined demand on seafarers. Then, in order to address the identified barriers, a systematic framework of improvement measures is developed. At last, the concept of continual improvement is highlighted for this framework, and a case study is selected to assess the effect of some measures.

2. Review of the Increasing Demand on Seafarers' Capacity for Energy Efficient Ship Operation

To address environmental issues and improve energy performance of shipping industry, there are a number of international, national and regional regulations, such as IMO framework, EU framework and Domestic Emission Control Area (DECA) of China. Furthermore, new technologies and equipment are being considered by relevant stakeholders, such as alternative fuels, renewable energy and so on. Therefore, MET should follow the development of these issues to continually update seafarers' capacity to fit these changes. At present, the capacity needed for seafarers can be divided into several dimensions, which are the knowledge of regulations, implementation of practices advised by IMO on board ships, implementation of LNG as a marine fuel, and implementation of other energy sources.

2.1 Knowledge of regulations

At present, the related regulations of energy efficient shipping are not covered in Chinese MET subjects. The United Nations adopted the Kyoto Protocol on 11 December 1997, in Kyoto, Japan, which entered into force on 16 February 2005. The Kyoto Protocol is an international agreement on climate change. Under the Kyoto Protocol, the regulation of GHG emissions from shipping was delegated to IMO (Buhaug et al., 2009; Psaraftis & Kontovas, 2014). In 1997, the MARPOL Annex VI was adopted by IMO to address air pollution and environmental problems by reducing emissions from ships. In 2011, the mandatory technical and operational energy efficiency measures were adopted by IMO as amendments of MARPOL Annex VI, which are EEDI and SEEMP. These mandatory measures entered into force on 1 January 2013. Furthermore, the Energy Efficiency Operational Indicator (EEOI) is introduced as a voluntary measure to compare CO_2 emissions from the current shipping fleets under MARPOL Annex VI. Then, in order to make GHG emissions visible, make SEEMP operate effectively and achieve an effective tool for future measures, the DCS was adopted by IMO on 28 October 2016. The DCS entered into force on 1 March 2018, which is following a three-step approach----Data collection, analysis, and decision-making.

2.1.1 Energy efficiency design index (EEDI)

The EEDI is for new ships, a very important technical measure to promote the use of more energy efficient technologies and engines. The EEDI set a minimum energy efficiency level per tonne mile for different ship size and type. By the implementation of EEDI, continual innovation and development of technologies are expected in the design phase of a ship. The ship-owners are free to choose any cost-effective solutions to attain the required energy efficiency level. The EEDI is expressed in grams of CO_2 per ship's tonne mile, and the smaller EEDI is the better design. The EEDI is calculated by a formula as follows:

EEDI (g CO_2/tonne. mile) =

$$\frac{\left(\prod_{j=1}^{n} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE} *\right) + \left(\left(\prod_{j=1}^{n} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME} **\right)}{f_i \cdot f_c \cdot f_l \cdot Capacity \cdot f_w \cdot V_{ref}}$$

Figure 2: The formula of attained EEDI

(Source: IMO MEPC.245 (66), 2014)

The main parameters are shown as follows: f_j: Ship specific design factor, P_{ME}: Main power, C_{FME}: Carbon factor of main engine, SFC_{ME}: Specific fuel consumption of main engine, P_{AE}: Auxiliary power, C_{FAE}: Carbon factor of auxiliary engine, SFC_{AE}: Specific fuel consumption of auxiliary engine, P_{PTI}: Power taken in (shaft motor), P_{AEeff}: Auxiliary power saved by waste heat, P_{eff}: Main power saved by new technologies, f_C and f_t: Capacity factor, Capacity: DWT/GTR, V_{ref}: Attained speed, f_w: Wave factor.

The result of the above formula represents a ratio between emission condition and transport work. The attained EEDI should be always smaller than the required EEDI. The required EEDI will be gradually tighter and tighter. It is show as follows:

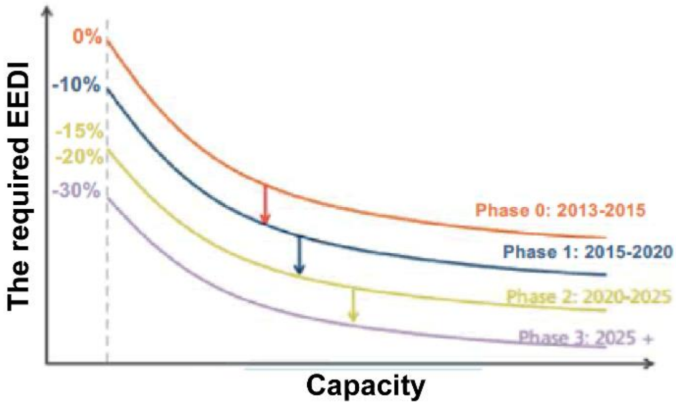

Figure 3: The required EEDI in different phases

(Source: IMO Module 2 – Ship Energy Efficiency Regulations and Related Guidelines, 2016)

The survey and certification of the EEDI should be conducted on two stages: the first is preliminary verification, which is carried out at the design stage; the second is final verification, which is finished at the sea trial (Perera & Mo, 2016).

In conclusion, the mandatory EEDI regulation is a very effective measure to achieve a continual improvement of energy efficient ship design. Furthermore, the calculation of EEDI is also very important to be known by ship operators, because the new technologies are operated by the operators, such as waste heat recovery system, shaft generator, shaft motor and so on. The feedback from operators can provide more space and opportunities for achieving less EEDI and improving ship design. In addition, if the operators know new technologies well, the performance of operation would also be further improved.

2.1.2 Ship energy efficiency management plan (SEEMP)

The SEEMP is required by regulation 22 of MARPOL Annex VI. On 28 October

2016. The guidelines for the development of a ship energy efficiency management plan (SEEMP) was adopted by IMO, which is to assist with the preparation of the SEEMP. There are two parts in the guidelines, the part 1 is aim to provide a mechanism for companies or ships for improving energy efficient ship operation; the part 2 provides the methodologies for the implementation of DCS.

In order to achieve continual improvement of energy efficient management for ships, the part 1 of the guidelines requires companies to follow four steps: Planning; Implementation; Monitoring; and Self-evaluation and improvement. The Planning phase is the most important stage for developing an effective and implementable SEEMP. In the Planning phase, by analyzing the present and past energy use and considering the requirements of company's energy policy, the expected improvement of energy efficient ship operation is determined. Furthermore, as not all measures can be applied to all ships, further measures for improving energy efficiency of ships should be identified in the Planning phase. The MET is also very important part of the Planning phase for effective implementation of SEEMP, for instance, the training matrix for raising awareness, providing appropriate training for new technologies or equipment.

In the Implementation phase, the measures identified in the Planning phase should be implemented by establishing an implementation system, and the significant activities should be recorded and documented. In the Monitoring phase, the EEOI is the primary monitoring tool, although other appropriate quantitative measures can also can be used. The formula for calculation of EEOI is shown in the figure 4.

$$\text{Average EEOI} = \frac{\sum_i \sum_j (FC_{ij} \times C_{Fj})}{\sum_i (m_{cargo,i} \times D_i)}$$

Figure 4: The calculation formula for Average EEOI

(Source: IMO MEPC.1/Circ.684, 2009)

The parameters are indicated as follows: i is the voyage number, j is the fuel type, FC_{ij} is the mass of consumed fuel j at voyage i, C_{Fj} is the fuel mass to CO_2 mass conversion factor for fuel j, m_{cargo} is cargo carried (tonnes) or work done (number of TEU or passengers) or gross tonnes for passenger ships, D is the distance in nautical miles corresponding to the cargo carried or work done.

The final phase is the Self-evaluation and improvement. In this phase, the feedback of the effectiveness of the planned measures and of their implementation should be analyzed for the next improvement cycle.

In conclusion, this continual improvement framework is crucial for the implementation of SEEMP. In the view of MET, apart from the essential education and training for the implementation of specific SEEMP of a company or ship, the education and training on science of management is also very important for raising the understanding and awareness of participants. For example, the data from engineering log-books and oil record books are very important for monitoring the effectiveness of measures, if the operators understand the continual improvement framework of SEEMP, more attention would be paid by them for recording work, and the quality of data would be improved.

2.1.3 Emission control areas (ECAs)

In order to reduce emissions including SO_X, NO_X, and PM, ECAs were firstly adopted by IMO in Annex VI of the MARPOL, and entered into force in 2005. By now, the ECAs include the Baltic Sea area, the North Sea area, the North American area and the Unites States Caribbean sea area. These areas have much stricter requirements for SO_X and PM emissions. In addition, the North American area and the Unites States Caribbean sea area also have additional limitation for NO_x emission (Chen, Yip & Mou, 2017). The requirements for ECAs is becoming more stringent, and the number of areas is also increasing. Furthermore, DECA of China was first adopted in 2015 to limit sulphur content of fuel for sea-going ships operating within Pearl River Delta, Yangtze River Delta, and Bohai Sea Water Area.

The content of MET should cover the ECAs, DECA and their development. As the compliance for the requirements is done by seafarers. The knowledge on the regulations is useful to improve the performance of compliance.

2.1.4 EU framework

EU has made a large number of efforts to improve energy efficiency of shipping industry. In the past two decades, the EU pushed IMO's process of regulation within some aspects. In 2006, EU began to consider energy efficiency, and the Energy Services Directive 2006/32/EC was adopted by EU, which set a target of 9 percent reduction in energy consumption within 9 years for member states of EU. Then, the Directive 2006/32/EC was replaced in 2012 by the Energy Efficiency Directive 2012/27/EU, which requires each member state to reduce energy consumption by at least 1.5 percent/year from 2014 to 2020.

Although the EU considers the IMO as the most appropriate international organization, which is responsible for regulation of GHG emissions from shipping, international responses (Kyoto Protocol, Paris Agreement, EEDI, SEEMP and EEOI) to the challenge of mitigating GHG emissions from international shipping are not sufficient. Therefore, EU decided to have its own climate and shipping policy. In 2015, Regulation (EU) 2015/757 of the European Parliament and of the Council was adopted, which aims to introduce a benchmarking tool for energy efficient measures of shipping. The tool is the Monitoring, Reporting and Verification (MRV) system. Then on 28 October 2016, IMO's Data Collection System (DCS) was adopted by MEPC 70.

In conclusion, for ship operators, it is essential to know the requirement of DCS and MRV, and master the procedures for submitting data. In addition, the ship operators' awareness of data quality control should be enhanced by MET for implementing the tools effectively. For data collection on ships, there may be some software employed on ships, therefore the training for the software is also an important part of MET.

2.2 Practices on board ships

There are a range of energy efficiency measures provided by the MEPC. 282 (70), which include fuel-efficient operations, ship handling optimization, waste heat recovery system, fleet management, cargo handling solution, energy management on ships, alternative fuels and renewable energy sources and so on. These measures can be employed individually or collectively for a ship. These practices are the cornerstone of energy efficient ship operation. Especially for improving MET, it is crucial to understand them very well. Additionally, by now there is no specific subject for the knowledge in Chinese MET.

2.2.1 Fuel-efficient operations

Before one specific voyage, the company and ship officers need to do a voyage planning. The planning usually follows the requirements of cargo arrangements and safety issues. Furthermore, without compromising the above requirements, energy efficient ship operation can also be achieved by some software tools, such as K-Nav ECDIS (Lu, Turan, Boulougouris, Banks, & Incecik, 2015; Tsou & Cheng, 2013). Weather routing is a common practice based on pre and during voyage weather forecasts that help improve ship performance by reducing the total resistance of a ship (Perera, & Soares, 2017; Vettor & Guedes, 2016). In addition, optimum voyage execution can be achieved by early notification of the next port of call for berth availability in order to adjust ship speed and arrive “Just-in-time” (Jia, Adland, Prakash & Smith, 2017; Moon & Woo, 2014). The fuel consumption of a ship and the CO_2 emission are a function of its speed. Therefore, slow steaming has been widely adopted to significantly reduce fuel consumption (Wang & Xu, 2015).

2.2.2 Ship handling optimization

When a ship is moving on water surface, the energy is lost by creating two systems behind itself, one is wake, and the other is wave system. Total resistance of a ship can be divided into 4 components, such as viscous resistance, wave resistance, air resistance, and appendage resistance. During ship operation, there are only few options for operators to reduce resistance, for instance, reducing transom immersion resistance and skin friction resistance. For transom immersion resistance, it can be reduced by controlling trim of a ship. For one draft, there is a trim condition with minimum resistance. On some ships, the trim of ships can be assessed by some software. On the other hand, for reducing skin friction resistance, it can be achieved by appropriate hull and propeller cleaning, and new technology-coating systems. In addition, in order to optimize ship handling, some specific train should be considered for engine control system, ballast water management system, integrated Navigation and Command Systems, and electronic controlled engines.

2.2.3 Waste heat recovery system (WHRS)

Exhaust gas from main engine contains a bigger percentage of energy, as shown in the figure 5. Comparing with other sources of waste energy, the exhaust gas is the most attractive one. Therefore, the Waste Heat Recovery System has been developing rapidly.

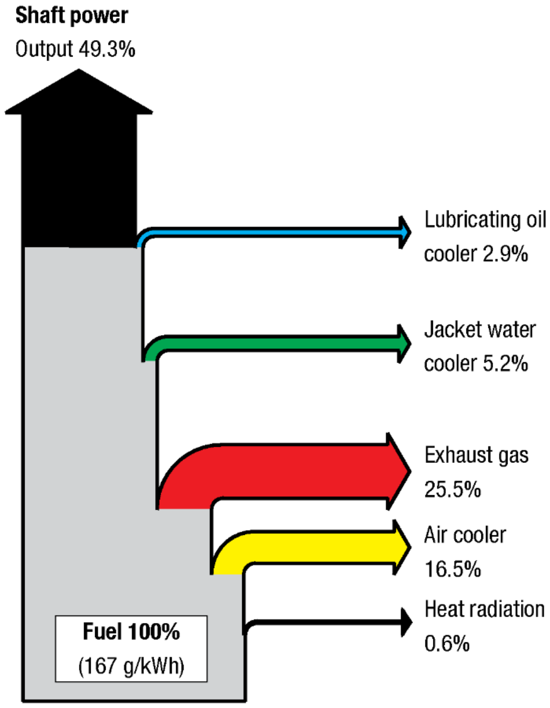

Figure 5: Heat balance for MAN B & W engine type without WHRS

(Source: MAN Diesel & Turbo Waste Heat Recovery System for Reduction of Fuel Consumption, Emissions and EEDI)

In the preliminary stage of WHRS system, the exhaust gas energy is only used for compressing fresh air by turbocharger, and producing steam by exhaust boilers. Because after turbocharger the temperature of exhaust gas is relatively low. For this type of WHRS, the requirements for MET is relatively easy, such as some train for cleaning equipment and some general knowledge for turbocharger and exhaust boilers.

However, with the increasing interest and requirements in emission reduction, the WHRS is becoming more and more complex. So the requirements for MET is becoming higher. For example, the MAN B & W is developing some different WHRSs for two-stroke main engine to produce electricity or additional propulsion from the exhaust gas, for instance, Steam Turbine-Power Turbine generator unit (ST-PT), Steam Turbine Generator unit (STG), and Power Turbine Generator unit (PTG). The above WHRSs can be used by different combinations to achieve a higher reduction. In addition, the WHRS can also work in parallel with a shaft motor, shaft generator and auxiliary diesel generators or be able to supply the total need of electricity for a ship.

In conclusion, the maintenance and control of WHRS are becoming more and more complex. In addition, the supply of electricity is a significant factor for ship safety. Therefore, more specialized knowledge and train are needed for operators by MET. Especially, universities and training centers of companies should cooperate for this issue, as lecturers in universities are good at providing professional knowledge and trainers in training centers have better background of practice operation.

2.3 Alternative fuel

At present, there are several factors changing marine fuel choices in the maritime industry. Firstly, international shipping represents a large part of local pollutant, especially along coastal areas, and the pollutant may result in significant health and environmental problems in exposed areas (IMO, 2014). Secondly, IMO has adopted a number of amendments to reduce the pollutant from ships, such as SO_X, NOx, PM, CO_2 and so on. Thirdly, Natural gas can produce much lower emissions than conventional fuel oil, and the difference of price between natural gas and low sulphur fuel oil is an economic driver for changing marine fuel to natural gas (Thomson, Corbett & Winebrake, 2015). Therefore, to reduce the atmospheric pollutant emissions from ships in China, the Ministry of Transport of China (MOT) and the National Development and Reform Commission of China have adopted a number of policies to popularize the application of LNG (Fan, Xu, Wu, Shi & Guan, 2018). The demands for LNG as a marine fuel is increasing very fast in China.

Norway is the world's leading maritime nation. It provides transportation for LNG, which leads to LNG trade increasing very fast, and remaining high competitiveness.

According to Chen, et al (2016), from 2004 to 2014, the highest annual growth rate and the second-highest average value of competitiveness among world's LNG exporters was Norway. The annual growth rate of Norway was 1.434, which will increase its influence in the future. The first LNG fuelled ship (Glutra) in the world was launched by Norway in 2001. At present, around 200 sea-going ships (In operation and under construction) are fuelled by LNG in addition to about 100 LNG carriers in the world. Most of LNG fuelled ships are operating in Norway including ferries, offshore support vessels, coast guard vessels/patrol vessel, product tanker, LNG tanker, fish fodder, ROPAX, barge and so on (Acciaro, 2014). In addition, from 1984, Norway already began to develop gas engines such as Dual fuel gas engines and Lean burn gas engines. Some research found that the trend of LNG fuelled ships is towards building smaller ship size and short distance, and Norway is the new building front-runner (Calderón, Illing & Veiga, 2016). Therefore, Norway is the best practice of LNG as a marine fuel by now in the world.

2.3.1 Training for LNG as a marine fuel in China

In China, an LNG fuelled ship was firstly introduced for inland shipping in 2010, and firstly introduced for a sea-going ship in 2013 (International Gas Union, 2015). The application of LNG as a marine fuel is still in the initial stage by now in China (Shi, Jing, Wang & Zhang, 2010). According to the requirements of Maritime Safety Administration of China and China Classification Society, the training for the crew working on LNG fuelled sea-going ships is carried out with reference to the special requirements for the crew on inland waterway ships. For example, the crew are qualified with a special training certificate awarded after theoretical and practical tests; The training frequency is 5 years, a revalidation is required after 5 years; The type of training includes basic and operational training, the basic training is aim to provide the basic safety crew with a basic understanding of LNG in question as a fuel including both theoretical and practical exercises; In operational training, deck and engineer officers are required to have special training beyond the general basic training, and all gas related systems on board, all manuals are to be used in the training (China Classification Society, 2013). In addition, there is no national regulation about training for operators of LNG bunkering and other shore-based operation, which is addressed by companies by now. By contrast, Norway has national regulations with mandatory requirements for training crew of LNG fuelled sea-going ships.

The Regulation of 17.June 2002 No. 644 concerning cargo ships with natural gas fuelled combustion engines.

The Regulation of 9.September 2005 No.1218 concerning construction and operation of gas-fuelled passenger vessels.

In 2016, Norway Maritime Authority lay down a new regulation on ships using fuel with a flashpoint of less than 60°C, which repealed and replaced the above two regulations. The background of the new regulation is the International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels (IFG Code), which entered into force on 1 January 2017.

With the adoption of the new Regulation, new requirements for qualification and certification for workers on board ships using Low-Flashpoint Fuels (LFF) were set in the amendments of Regulations of 22 December 2011 No. 1523 on qualifications and certificates for seafarers (Norwegian Maritime Authority, 2018).

Therefore, a lesson can be concluded that Norway timely developed the specific regulations for training seafarers working on LNG fuelled sea-going ships, and updated the regulations in due course following the requirements of IMO and development of technology. For China, the regulation in this area is almost blank. So the authority of China should speed up the process to improve the regulatory framework and pertinence of training.

2.4 Renewable energy sources

Although LNG as a marine fuel can dramatically reduce SO_X, NO_X and PM, CO_2 emission reduction is not sufficient by LNG. LNG as a marine fuel is only a transitional but not sustainable approach. In order to radically reduce emissions, the renewable energy sources are estimated to have a big potential such as wind power, solar power. Furthermore, batteries, fuel cell, nuclear propulsion, hybrid propulsion are also considered to overcome the impact of fossil fuel and the related environmental issues. However, the employment of these measures can reform ship operations deeply, and the requirements for MET will also change remarkably for developing competent seafarers. Therefore, it is very important to understand the new technologies and carry out some predictive measures for the future.

2.4.1 Wind power

Generally, there are two types of technologies using wind energy for ship propulsion, such as Flettner rotor and towing kite. The Flettner rotor was invented by Anton Flettner in the 1920s, which is a vertical cylinder mounted on the deck of a ship and rotated by a motor (Traut, et al., 2014; Talluri, Nalianda & Giuliani, 2018). The principle of working is the Magnus effect. In sideways wind, the Magnus force creates a lift force to propel the ship. The key parameters of a Flettner rotor are the lift coefficient that is for the thrust, and the moment coefficient which is for the power needed

Towing kite as a type of ship propulsion started from 1980s (Traut, et al., 2014). As most of time kites are flying in front of a ship, deck space can be saved comparing with Flettner rotor. The best condition of working is in cross-wind. Higher wind speed can get higher thrust. However, the rope should be able to bear relatively large force. The key parameters of a kite are the drag and lift coefficients and the limitation of the force of the rope.

2.4.2 Solar Power

Solar power for ships is mainly the conversion from sunlight energy to electricity by photovoltaic methods. Photovoltaic effect is the basic principle of converting light into electric current by photovoltaic cells. The power generated by photovoltaic methods is relatively low compared to the requirement of ship propulsion. However, the power can be benefit for auxiliary power requirement. The key factors for solar power are the latitude and the angle of photovoltaic cells positioned (Royal Academy of Engineering, 2013). One of the main barriers is the requirement of large deck surface area on ships for photovoltaic cells. Therefore the car carriers are suitable for this technology.

2.4.3 Fuel cell and batteries

Fuel cells and batteries are recognized as the zero emission technologies to replace fossil fuel for ships. Some studies and practices for implementing the two technologies have been carried out for ships.

There are a number of types of fuel cells, which are Polymer electrolyte membrane fuel cells, Direct methanol fuel cells, Alkaline fuel cells, Phosphoric acid fuel cells, Molten carbonate fuel cells, Solid oxide fuel cells, and Reversible fuel cells (Department of Energy, 2018). However, the fundamental process for fuel cells is the same for producing electricity, which is an electrochemical process producing electrical energy by electrons flow inside a fuel cell (De-Troya, Alvarez & Fernandez-Garrido, 2016). In addition, a fuel cell is powered by liquid hydrogen or compressed hydrogen gas.

Batteries and fuel cells are the popular power options for automobile industry. The technology of batteries is also developing very fast. The main type of batteries for ship power is the secondary batteries, which can recharge for many times. Minnehan & Pratt (2017) have done some research on the application of fuel cells and batteries. They stated that fuel cells are more capable for a wide range of ship sizes and requirements of durations, because the hydrogen tanks have higher energy storage density comparing with battery systems, especially, the energy storage density of liquid hydrogen tanks can reach 1.3 KWh/L. However, for small vessels, which require high power for short durations, the battery system is better than fuel cell systems for meeting the requirements. The reason is due to the fuel cell system size. In this case, the fuel cell system spends more space than battery system, and then the cargo-carrying capacity will be reduced accordingly.

2.5 Summary

With the development of technology and more stringent regulations, the demand to seafarers' capacity is becoming higher and higher. As the main method for developing capacity of seafarers, MET should also be improved accordingly. Regulations are mainly used to unify awareness and actions for specific topic such as energy efficiency. Therefore, the knowledge of regulations should be highlighted in MET, especially, the development of regulations should be tracked timely. Each ship operation is done by seafarers. Hence, the basic knowledge and principle of new technologies commonly used should be understood well through MET. For new technologies, although application of those technologies is limited up to now, MET should build solid foundation for seafarers to fit future requirements.

3. MET-related Barriers for Energy Efficient Ship Operation: The Case of China

Based on the need of MET in identified areas of energy efficient ship operation in Chapter 2, this chapter further looks into the present situation of MET in China and identifies the barriers in Chinese MET to achieve energy efficient ship operation.

To begin with the current situation, Chinese MET is largely divided to two systems: one is education for undergraduate (4 years) and junior college (2 years); the other vocational education without degree. The institutions for MET include around 10 universities, over 30 colleges and over 100 training centers. The content of MET is education courses and training programs for students (future operators) and seafarers (existing operators). For students, the courses and programs aim to build up the sound foundation of knowledge and basic skills for future ship operation. For seafarers, the courses and programs are for updating knowledge and accommodating further requirements of operation.

In addition, there are two competent authorities that are responsible for MET matters, one is the Office of Education and Training of Ministry of Transport (OET); the other the Maritime Safety Authority of China (MSAC). The OET is in charge of industry guidance, and the MSAC takes charge of administration of examination, certification and management of Chinese seafarers.

The bottom-up method will be carried out for identifying the barriers existing in the MET in China. The barriers are divided into several aspects, which are arrange of courses and training programs in universities, colleges and training centers, improvement of competency of teachers and trainers, cultural construction for energy efficient shipping in universities and colleges, MET policy from institutions and competent authorities, and lessons collected from other industry sectors such as Manufacturing industry and Construction industry.

3.1 Barriers identified by literature review and questionnaires

A literature review was carried out following several steps, which are formulation of the key question, designing the search method, identification and application of selection criteria, and implementing study. The key review question is what barriers are existing in the MET for energy efficient ship operation. The search method is comprehensive. The articles are mainly searched from two databases (Science direct and Google Scholar). The keywords for searching articles are "barriers for implementing maritime education and training for energy efficient shipping", "development of maritime education and training in China for energy efficient shipping", "energy efficiency in China", and "maritime education and training".

In addition, the criteria for selecting articles is whether it relates to the review question, and whether it is addressing the review question. In the phase of implementing study, only empirical evidence was selected for the review question, and the evidence may be from qualitative research, observational research or experimental research. The number of articles reviewed is 150.

However, the information on barriers from literature is limited, therefore data was also collected from Chinese field person, namely teachers, seafarers, managers of MET, and related managers of shipping companies. The research question of this study is not a common question, which is not easy to be understood without enough communication. Therefore, the questionnaires are mainly sent by emails with a short explanation for this research question. By the end of July, 89 replies had been received, but 3 replies of them do not have reference value for this study. The 86 replies are presented as follows: 21 replies of teachers are from universities (16) and colleges (5); 45 replies are received from seafarers; 13 replies are from managers of MET (University: 8, competent authorities: 5); 3 replies are from related managers of shipping companies; and 4 replies are from training centers.

The respondent sectors are shown in the figure 6.

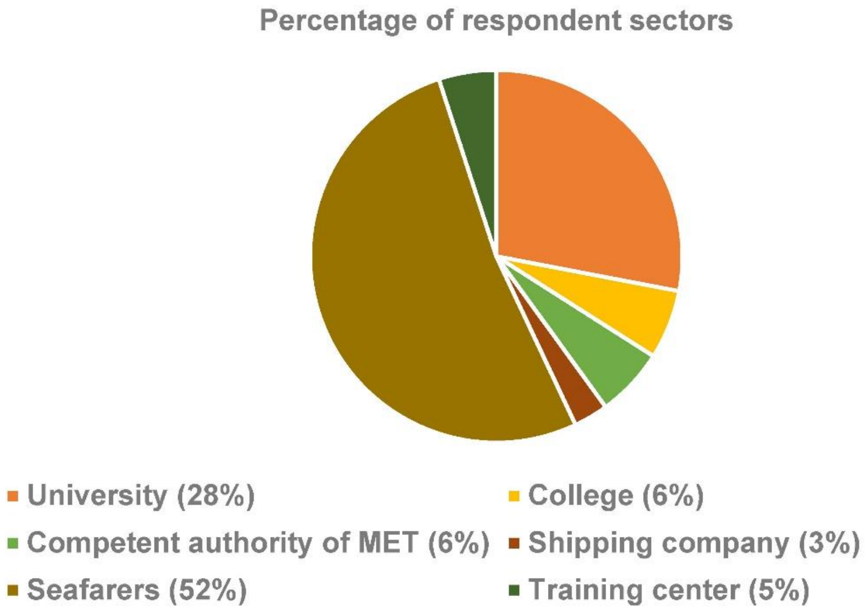

Figure 6: The percentage of respondent sectors of questionnaires

(Source: Author)

3.1.1 Results of the questionnaires and literature review

There are 21 barriers identified by questionnaires and literature review, the details are shown in the figure 7. The barriers are directly collected from questionnaires and literature, some of them may not be well-defined, and their frequency is calculated by number of mentioned times divided by total number of barriers including repeated. The formula is presented as follows:

$$\textbf{Frequency} = \frac{\textbf{Number of times mentioned for one barrier}}{\textbf{Total number of barriers from all sources including repeated ones}}$$

Figure 7: The formula for the calculation of frequency

(Sources: Author)

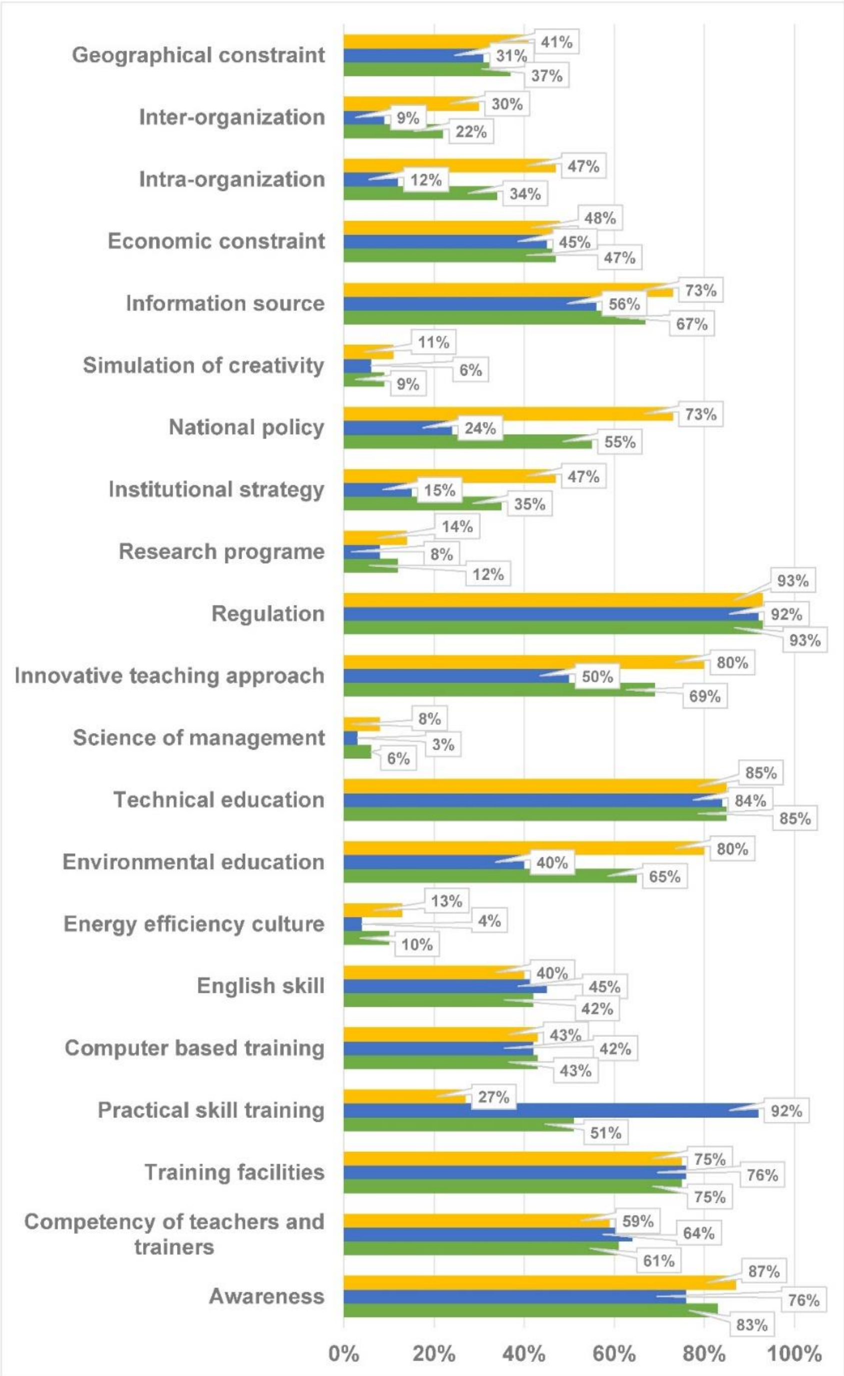

Figure 8: The barriers and their frequency identified by literature review and questionnaires: the yellow bars are from literature review; the blue bars are from questionnaires; the green bars are total by both.

(Source: Author)

It can be seen that frequency of some barriers mentioned in literature review is much higher than in questionnaires, which are energy efficiency culture, environmental education, science of management, innovative teaching approach, institutional strategy, national policy, simulation of creativity, information source, inter and intra-organization. Because the above barriers are not on the surface of water, most of researchers started to focus on them after some research. But operators focus on more obvious obstacles such as practical skill training.

The presentation for each identified barrier is stated as follows:

The barrier on awareness

The total frequency of awareness is 83%. The awareness is the perception or concern about environmental issues affected by energy efficient ship operation for seafarers, teachers and trainers, and managers. In general, the main objective of MET is to make students meet the requirements of examination and certification, and successfully take up an occupation on board ships. In the other words, energy efficiency is not a crucial part of the examination, therefore, the priority of energy efficiency is not high in MET. At present, although environmental issues such as extreme weather events, sea level rise, increase in global temperature, ocean acidification, and reduction in the Arctic and Antarctic ice cover extent are gaining more and more attention, the relationship between environmental issues and energy efficient ship operation is still not fully recognized by seafarers, teachers and trainers, and managers in China; considering the share of Chinese seafarers in the global manpower supply, more attention should be placed to this aspect by MET. Although IMO have done three GHG emissions studies and the reports are available online, such IMO related studies should be effectively used in MET in China.

The barrier on competency of teachers and trainers

The total frequency of competency of teachers and trainers is 61%. The competency of teachers and trainers is also a key factor affecting MET. In universities or colleges, although most of teachers have certifications of seafarers, the practical experience of them on board ships may not be enough or not up-to-date because of a considerable amount of time interrupted for being away from sea. In the other words, some teachers cannot understand ship operation very well. Only few teachers can keep working on board ships as an engineer or officer. There are all kinds of reasons for this problem, but the main point is lack of specific incentive policies from university or college, and competent authority level, for example, the salary of teachers working on ships should be higher than working on land. On the other hand, energy efficiency measures adopted by IMO are relatively new, hence teachers are not familiar to these measures. Therefore, the project of updating knowledge for teachers should be carried out in China. Furthermore, the cooperation framework between universities and training centers should be developed and enhanced.

The barrier on training facilities

The total frequency of training facilities is 75%. Training facilities refer to some equipment and site for training of energy efficient ship operation such as simulators of navigating for weather routing, engine control system for slow steaming, and software used on board ships for example, for trim optimization and voyage planning. The capital and operational cost for the facilities are the biggest challenge for universities or colleges. In order to address this problem, financial support from government or competent authorities is extremely important.

The barrier on practical skill training

The total frequency of practical skill training is 51%. The practical skill training is some training that directly relates to energy efficient ship operation. For example, the operation and maintenance for Waste Heat Recovery System is relatively complex, it is not enough that operators just know the basic principle of the system; and voyage planning also requires some practical skills to make a suitable plan. In addition, the computer based training is a training method employing computer to help operators to understand complex systems or some systems that cannot be installed in lab or training site such as wind rotor.

The barrier on English skill

The total frequency of English skill is 42%. English skill is a traditional challenge for Chinese seafarers, and also for some teachers and trainers. As the language environment for English is not good in China, and teaching and examination system are not effective enough, for example, speaking skill should be given more weight in the teaching and examination. The English skill especially for communication should be enhanced by MET. Because communication among operators is a significant factor for energy efficient ship operation, for instance, when the Just in time is considered on board ships, operators need to communicate with stakeholders such as shipping companies, ship owner and port authority for decision making. In order to address this issue, it is better to use English as a teaching or training language for some appropriate subjects. In this case, teachers and trainers should be able to use English for teaching or training very well, but most of them do not have sufficient background related to English. In addition, the advanced technologies for energy efficient shipping are generally presented in English, if they cannot fully understand the materials, teaching would be also affected. For this problem, some policies for improving English skill of teachers and trainers should be considered by managers and competent authorities, for example, encouraging them to study in WMU.

The barrier on cultural construction

The total frequency of cultural construction is 10%. Fostering Energy efficient culture in shipping is a new topic for MET. By the culture construction in universities or colleges, the effect of teaching and training will be improved dramatically. And this improvement will be benefit for a long time throughout the careers of operators. In order to foster the culture within MET, there are a number of ways to promote the culture in a cost-effective manner, for example, implementing ISO 50001 to improve building energy performance of universities, and encouraging students to participate research programs for energy efficient shipping.

The barrier on environmental education

The total frequency of environmental education is 65%. Environmental education is a big topic for universities or colleges. At present, the environmental education is not obtained much attention in MET in China. Only some subjects may include little general information for this topic, but it is not enough and updated timely. It is a significant factor for improving awareness of operators. Therefore, in the arrangement of courses, environmental education should be given more weight.

The barriers on technical and management education

The total frequencies of technical and management education are 85% and 6%. Technical education is some teaching content for specific technologies that have a big potential for future application on board ships such as LNG as a marine fuel, fuel cells, batteries, wind rotor, air lubrication and other new types of ship design. Compared to technical education that builds a solid foundation for energy efficient ship operation, the education on science of management is also very important for operators, especially for students studying in universities. Because universities are also developing future maritime leaders for shipping industry. Professional basic knowledge of management can be benefit for continual improvement of ship operation, when operators get the position of managers. On the other hand, the knowledge of management, theories and practices also help operators to understand company policies on energy efficient ship operation, and then it is expected that the performance of operators be improved too.

The barrier on innovative teaching approach

The total frequency of innovative teaching approach is 69%. The innovative teaching approach is the implementation of some advanced tools for teaching such as multimedia, simulation, and e-learning hubs. These tools are beneficial for better understanding of obscure knowledge or complex system such as the electrochemical principle of fuel cells, how to make voyage planning and whether routing.

The barrier on regulation

The total frequency of regulation is 93%. Regulation is a traditional topic in MET, especially international regulation. IMO has adopted a large number of regulations, amendments and guidelines for energy efficient shipping, which have a significant value for improving energy efficient ship operation by MET. However, Chinese MET does not provide sufficient presentation for regulations of energy efficiency by now. And the information on energy efficiency should be updated timely following the progress of IMO.

The barriers on research program and policy

The total frequencies of research program, institutional strategy and national policy are 12%, 35% and 55%. The research program is some studies for improving energy efficiency of shipping. From the view of MET, the research work can help teachers and students to raise awareness and can enhance energy efficiency culture construction. The institutional strategy and national policy were already mentioned above. The development of MET cannot be achieved without the support of institutional strategy and national policy. By now, there is no national policy for improving MET for energy efficient ship operation in China. In some universities, there are some strategies encouraging teachers to keep working on board ships, but the strategies are not effective enough.

The barrier on simulation of creativity

The total frequency of simulation of creativity is 9%. The simulation of creativity can be treated as an example of research program. Simulation is a cost-effective method to carry out research for students in the initial stage. The information source is a wide concept for energy efficiency measures. In China, information for students is mainly limited in the scope of textbook, and a textbook is generally updated every 5-10 years in universities or colleges. Therefore, energy efficiency measures cannot be renewed timely. The updating work is up to teachers' sense of duty in the daily class.

The barrier on economic constraint

The total frequency of economic constraint is 47%. The economic constraint mainly relates to capital cost and operational cost for training equipment and sites. For example, DMU has two training vessels, one is YUKUN vessel built in 2008, and the other is YUPENG vessel built in 2017. The capital cost for the YUKUN vessel is almost 29.4 million US dollars, and the operational cost is around 2.94 million US dollars per year. The capital cost for YUPENG vessel is about 50 million US dollars. Training vessel is a very effective tool to train students, especially for energy efficient ship operation. However, the capital and operational cost is a big challenge for universities.

The inter-organizational barrier and geographical constraint

The total frequencies of the inter-organizational barrier and geographical constraint are 22% and 37%. The inter-organizational barrier and geographical constraint are almost presenting similar issue. The quality of MET, resources available, and infrastructure vary in different institutions. For example, the frontrunner of MET in China should be DMU, DMU's YUKUN vessel is specially designed for MET without any cargo space, and DMU has a land-based engine room lab (Capital cost: 7.4 million US dollars), which has each equipment of traditional ship engine room and can be operated as working on board ships. The inter-organizational barrier focused on the cooperation among institutions such as universities and training centers. Each institution has its own advantages, well-designed cooperation will be benefit for each one.

The intra-organizational barrier

The total frequency of intra-organizational barrier is 34%. The intra-organizational barrier focuses on the cooperation of different departments in one institution. For example, there are many departments in a university in China such as office of

Educational Administration, department of Marine Engineering and Navigation, office of Science and Technology Administration, office of Human Resources, department of Students' Affairs. Each above sector is in charge of some tasks that relate to MET. The improvement of MET relies on the effective and efficient cooperation of these sectors.

3.1.2 Categorizing barriers by online workshop

There is some overlap among the barriers identified by literature review and questionnaires. In order to get more scientific, objective and comprehensive barriers, an online workshop was carried out to analyze and categorize the barriers. The workshop contains 11 educators including 2 managers and author. The educators are required to have at least 10 years' experience of education and training, and be the experienced Chief Engineer or Captain. The managers are required to have at least 10 years' experience in the management of MET. The online workshop was held by WEI CHAT software and email. The content and results of the workshop was recorded and documented. The record and some screenshots of the workshop are shown in the Appendices.

The criteria for categorizing barriers is as follows:

Dividing the barriers into several aspects, which are courses, pedagogy, cognition practice, and cultural construction. For each aspect, the barriers are categorized from 4 dimensions including human resource, financial resource, other resource, and policy. Four dimensions were identified because human beings including teachers and students, financial support, and policy are the main factors affecting MET, and the other factors of MET can be included in the other resource.

According to the results of online workshop, the detail of barriers is shown in the table 1.

Table 1: The barriers identified and categorized by a workshop

(Source: Author)

Aspects of barriers	Dimensions of each aspect	
Courses	Human resource	Poor awareness of environmental issues and its relationship with ship operation (For teachers and trainers)
	Financial resource	High capital and operational cost for training facilities
	Other resource	Limited by textbook; Poor access to latest technologies and regulations; Lack of content of economics and management; Lack of environmental education
	Policy	Lack of support from national policy and institutional strategy for perfecting courses system
Pedagogy	Human resource	Poor awareness of environmental issues and its relationship with ship operation (For students and seafarers); Poor English skill; Weak competency of teachers and trainers
	Financial resource	High capital and operational cost for innovative teaching approach
	Other resource	Lack of training facilities; Weak

		employment of innovative teaching approach; Weak cooperation of intra-institution
	Policy	Conflict of cooperation of inter-institution; Lack of support from institutional strategy for innovative teaching approach
Cognition practice	Human resource	Insufficient competency of teachers and trainers
	Financial resource	High capital and operational cost for training facilities
	Other resource	Limited training facilities; Limited time for practice; Compromise with safety issues
	Policy	Insufficient cooperation of Intra-institution; Insufficient support from national policy
Cultural construction for energy efficiency	Human resource	Lack of awareness of recognizing importance of cultural construction for energy efficiency; Lack of experts for this topic
	Financial resource	High investment for implementing projects and standards; Limited budget
	Other resource	Weak basic foundation and experience for this topic

	Policy	Lack of support from national policy and institutional strategy

During the online workshop, some new ideas were added in the barriers, which are barriers for cognition practice and additional information for cultural construction. The cognition practice is a key part of MET, which is similar with a field study. Students normally study on a training vessel following arrangements of cognition practice for one month. This is the first time for students to know vessels and to understand what the job content of seafarers is when a ship is sailing, anchoring and berthing, and a good opportunity for them to apply for the knowledge studied in the class. Therefore, the cognition practice should be highlighted for improving MET for energy efficient ship operation. Furthermore, the cultural construction is a new topic for MET of China. As the energy efficiency is not a flash in the pan, it is a crucial concept for sustainable development. Therefore, a systematic framework of measures is significant for continual improvement of energy efficiency. The cultural construction is a key component of the framework. Hence, the cultural construction in MET should be given more attention and carried out with the least delay possible.

Identifying and categorizing barriers is for developing improvement measures to improve MET for energy efficient ship operation. However, the lessons of other industry sectors should also be considered as a reference before developing measures.

3.2 Critically review on barriers in MET of China

In order to develop the systematic framework of measures to overcome the barriers identified, the criticality of the barriers should be fully studied. Some previous studies have carried out a number of research to determine the prioritization of gaps for energy efficient shipping. For example, Nagesha & Balachandra (2006) employed the analytic hierarchy process (AHP) to analyze prioritization of barriers to energy efficiency in small industry clusters. The study stated that the top barriers were the financial and economic barrier and behavioral and personal barrier.

However, the barriers in MET are more interdependent than barriers to energy efficient industry. Because MET can be recognized as an action, the courses, pedagogy, cognition practice, and cultural construction are the 4 key components of this action. In the other words, without any one of the 4 components the MET action cannot work or cannot be improved continually. In addition, the theory of marginal effect also can provide a clear explanation for the relationship of the 4 aspects of MET.

The marginal effect states that the outcome of an action changes when one of covariates changes, and other covariates are kept fixed. According to the theory of marginal effect, the covariates should be changed together to obtain continual improvement of the action. Therefore, there is no need to study the prioritization of the barriers in MET. The improvement measures should consider the 4 aspects of MET synchronously.

3.3 Summary

In this Chapter, MET-related barriers for energy efficient ship operation were identified by literature review, questionnaires and an online workshop. The first stage was to find some general barriers from other research results and survey, then the online workshop was carried out to get the objective and comprehensive presentation of the barriers. Finally, for overcoming the barriers some critical discussion on MET-related barriers of China was carried out and reached the point that the barriers in MET are more interdependent than barriers to energy efficient industry.

4. The Systematic Framework of Improvement Measures for Overcoming the Barriers in MET of China

Several barriers in MET of China were identified in the previous chapter. This chapter presents the ways in which Chinese MET should consider to overcome these barriers. Measures to overcome the barriers in MET of China are developed from the 5 aspects, courses, pedagogy, cognition practice, cultural construction and policy making as shown in figure 8. Two subjects are designed for overcoming the barriers of courses, a project is designed for improving pedagogy, suggestions for additional training for educators are provided for cognition practice, and an international standard (ISO 50001) is introduced for universities or colleges to enhance cultural construction. At last, according to the lessons from other industry sectors, recommendation for policy making are provided for institution and competent authorities.

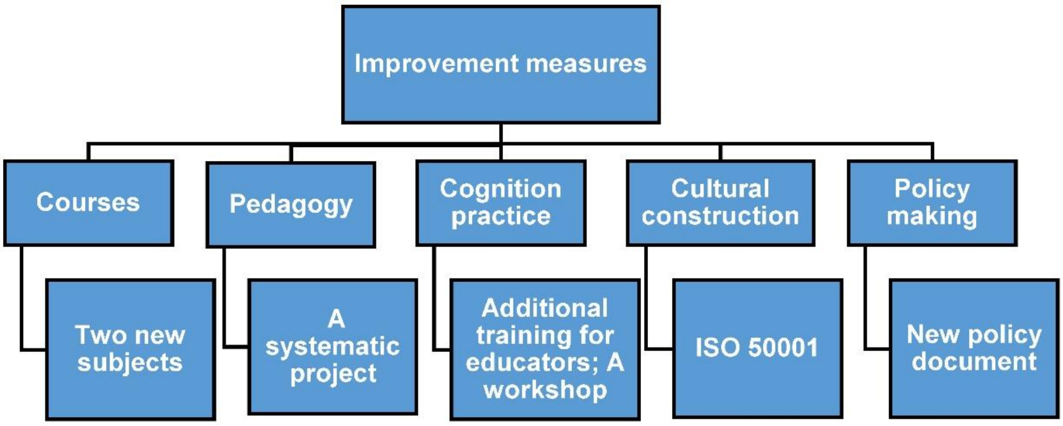

Figure 9: The framework of improvement measures

(Source: Author)

4.1 The subjects designed for overcoming the barriers of courses

From the view of knowledge, the barriers of courses identified in 3.3.2 can be divided into two parts, one is basic knowledge for environmental education, regulation and other fundamental knowledge such as science of economics and management; the other is technical knowledge for technical and operational measures and new technologies for energy efficient shipping. Therefore, two subjects are developed according to the two parts of barriers. The outlines of the two subjects are shown in the Table 2 and Table 3 in Appendices.

4.2 Project for improving pedagogy

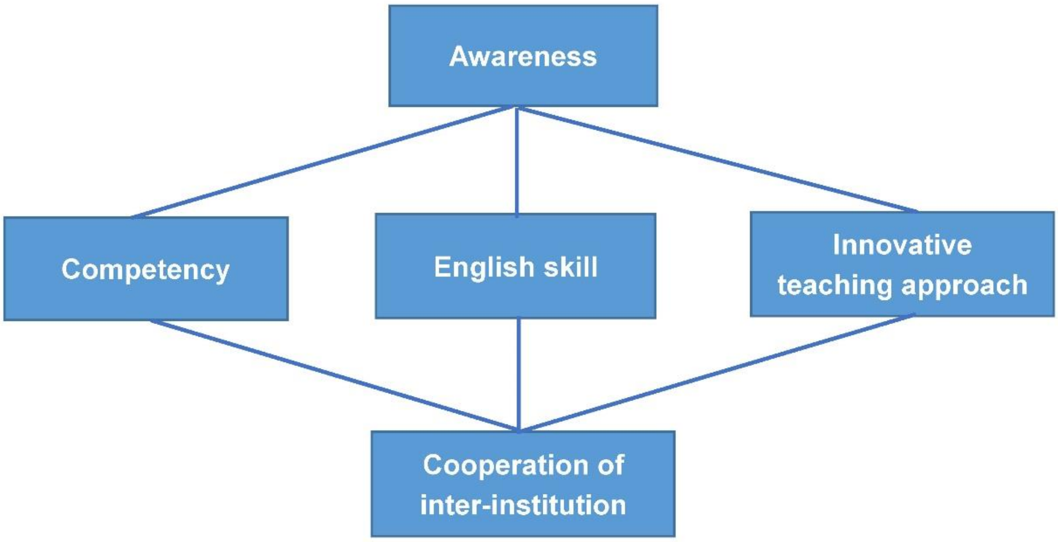

Figure 10: The framework of the project for improving pedagogy

(Source: Author)

The basis of the project is to raise teachers' and trainers' awareness of energy efficient ship operation. Once the awareness is raised, the other measures can be implemented effectively. Therefore, raising awareness is considered among all measures in this project. The main measures are designed from 3 aspects, which are competency of teachers and trainers, English skill, and employment of innovative teaching approach. In addition, the effect of this project is enhanced by the cooperation of inter-institution. There are a large number of institutions working on MET in China. The lessons from EU Eco-port project can be introduced for managing the cooperation mechanism. The detail of this project is presented as follows:

4.2.1 Competency of teachers and trainers

The competency focuses on practical skills of ship operation, and knowledge of regulations and new technologies. At present the technology of ship operation and operational requirements from regulations are developing very fast. Therefore, the practical skills of teachers and trainers should be updated regularly by working on board modern ships. The related institution should adopt specific incentive rules to encourage teachers and trainer to keep working on board ships.

Further, there is a dramatic difference between what people can do and what they are willing to do. According to Maslow's hierarchy of needs theory, the first level of needs is physiological needs, the second level is safety needs, the third level is belongingness and love needs, the forth level is esteem needs, and the highest level is self-actualization. Normally, the material basis determines the superstructure. By now, in China the difference of salaries between working on board ships and working on land is not significant. Therefore, it is very difficult to make teachers and trainers to work on ships on their own initiative.

In order to address this issue, the institution should provide more subsidy rather than reducing their salary when they work on board ships.

In addition, to motivate the learning by using a game theory, a practical skill contest can be held yearly in institutions for teachers and trainers. The content of competition should cover all potential measures provided by SEEMP and some selected new technologies that are commonly used on board ships. The results of the contest should be linked with professional title evaluation and some attractive rewards.

Furthermore, a knowledge contest should also be held to encourage teachers and trainers to improve themselves timely. The competition should include regulations adopted by IMO (including related guidelines), present application of new technologies such as LNG as a marine fuel and wind rotor, analysis of best practices and so on. Also, the results of the knowledge contest should be considered in professional title evaluation.

Moreover, Institutions should encourage closely related teachers to attend IMO meetings. Thus, the teachers can better understand the working process of IMO regulations, and follow the new progress in good time. In addition, this opportunity can also build a foundation for them to attend IMO's discussion and working groups.

4.2.2 English skill

English skill is a significant tool for energy efficient ship operation. This part of the project focuses on improving students' English skill, and teachers' and trainers' English skill. The teachers' and trainers' English skill is the basis for improving students' English skill. Therefore, the first stage of this part is to improve teachers' and trainers' English skill, which can be carried out from several ways as follows:

An education and training plan for teachers and trainers should be implemented for improving their English level. The plan should be more practical than general training. Experienced Experts with better skill are invited as advisors. Most of content this education and training is not giving lectures for trained person, but the trained person should be given more chance to practice English skills such as speaking and writing skill. In addition, the plan should be tailored at regular intervals for specific specialization such as marine engineering and navigation. Furthermore, there should be a strict and practical examination system at end of each plan. Without the permission of the examination system, the teachers and trainers cannot offer lectures for students in English. After two years, the permission should be validated again by the examination system.

Furthermore, some mandatory measures can be considered by institutions. For example, every five years, the teachers giving lectures in English have to study or be trained abroad for at least three months. And the average grade of the study or training have to be B+ (75%) or above.

For improving students' English skill, the main way is taught or trained in English, especially, the specialization courses should be taught in English. In this part of pedagogy, students should be encouraged to attend the process of teaching and have more chance to speak English and practice English skill. Culturally, Chinese students are not used to question teachers when teachers are presenting. This way of thinking should be changed by some incentive polies to encourage them to ask questions during lectures, for example the student who asks questions can receive a nice gift. By this change, the students can have more chance to practice speaking skill, and if a student can ask questions during the presentation, he/she has to pay more attention for the class, therefore, the effect of teaching is also improved. But, the requirements for teachers and trainers to adapt this change are much higher than before in terms of knowledge level and teaching skill.

Moreover, the students should be required to use English in their self-study after class. This is a big challenge for Chinese students, and the main factor affecting Chinese students' English skill. In order to address this challenge, the cooperation between teachers and department of Students' Affairs should be enhanced. For example, several classrooms can be selected only for English, anybody discussing in this type of classrooms has to use English. Then by some group works, the students' English skill can be improved dramatically.

4.2.3 Innovative teaching approach

With the development of information technology, and students' way of thinking, traditional teaching methods are becoming outdated and difficult to satisfy the needs of modern education and training. Innovative teaching approaches can enhance the effect of teaching and is more attractive than traditional methods. There are a number of choices for innovative teaching approaches such as Audience response technology, Long-distance teaching, Flipped classroom, and Active learning (Sivarajah, Curci, Johnson, Lam, Lee & Richardson, 2018). For the purpose of this study, the Flipped classroom is highlighted as follows:

The flipped classroom is remarkably different from traditional classroom in terms of employment of online presentations, videos or reading materials, and content for education and instruction are delivered to students before class. The learning process of flipped classroom is more active than traditional one. The main content of flipped classroom is solving some practical issues, case studies, and discussions with application of knowledge that have been learnt before class by self-study (Sharma, Lau & Doherty, 2015). In order to achieve flipped classroom, there are several components needed to be considered, such as flexible environment of teaching, shift of learning culture, Intentional content, and professional educators.

There are a number of advantages for implementing flipped classroom. For example, compared with traditional one, students already get basic knowledge for the class, then in the flipped classroom, students have got more chance to discuss with educators when applying the knowledge. Therefore, learning effect is improved. Additionally, by implementing flipped classroom, students can review the presentations and other materials as many times as they want.

4.2.4 Cooperation of inter-institution

The above measures aim to improve MET pedagogy. But the cooperation of inter-institution is aiming to improve pedagogy of MET at national level. As mentioned above, there are more than 140 institutions for MET in China, therefore, the cooperation of these institutions is significant for the sustainable development of MET pedagogy. For developing a better cooperation framework among MET institutions in China, the best practices of EU Eco-port should be studied and the lessons extracted from management of Eco-port can be introduced for China.

In 1974, the European Commission set up a Port Working Group. Then the European Sea Ports Organization (ESPO) was born out of the Group, which represents its members (European sea ports) in terms of common interest, views and values in policy making and European institutions. As one of significant initiatives, Eco-port was created in 1997 by ESPO to make a level playing field in Europe for port environmental management by cooperation and sharing knowledge and experience between ports (ESPO, 2018). There are two tools provided by Eco-port, which are Self-Diagnosis Method (SDM) and Port Environmental Review System (PERS).

It is very easy to become a member of Eco-port, and free of costs. The requirement is just registering on the website of Eco-port, and then finishing a questionnaire of SDM. After finishing the above requirement, a sea port can enter into the Eco-port network. As a member of Eco-port, the port has access to all tools of Eco-port to compare own practices with European benchmark, and improve environmental performance by professional advices (Eco-ports, 2018). By now, the number of Eco-port members is 97, Countries joined are 24.

In China, there is also a similar organization managed by Ministry of Education of the People's Republic of China, which called the Teaching Guiding Committee for Maritime Education. The Committee is structured by experts of institutions for MET. However, the Committee lacks some effective tools to guide development of MET. Fortunately, the SDM and PERS tools provide references for China. For example, by another SDM for MET, an institution can identify its risks and establish priority for action, then the institution can improve MET performance according to advices from experts, at last the MET performance of the institution will be audited by the PERS for MET. By this way, the overall level of MET in China will be improved continually.

4.3 Suggestions for cognition practice

The cognition practice is the first time for students to know vessels and the job content of seafarers in China, and normally it is for the third year students of universities. The main task of students in cognition practice is to look at seafarers' daily work, and do some easy work supervised by seafarers. Additionally, the students are given some lectures about general introduction to the training ship. Most of seafarers who are supervising students on training vessels are also teachers of universities.

Therefore, the cognition practice is a very good opportunity for educating and training of energy efficient ship operation. For the purpose of this study, some suggestions for cognition practice are discussed as follows:

The educators on training vessels should have specific training of energy efficiency of shipping, for example, the Subject 2 designed in 4.1 can be considered as a reference for the training.

Furthermore, a workshop for students can be carried out in one cognition practice for a week. The details are designed as follows:

a) Students are divided into several groups, each group includes 4-5 students.

b) Each group should selects one topic to finish a group assignment and a presentation about energy efficient ship operation. The topics can be: lighting system of the training vessel and energy consumption; ship speed and fuel consumption; electronic supply and fuel consumption; suggestions for improving energy efficiency of the training vessel on other aspects such as steam system and cooling water system.

Through the workshop, students can get a basic picture of energy efficient ship operation, and the results of workshop can improve students' awareness of importance of energy efficiency for shipping.

4.4 Recommendations to cultural construction for energy efficiency

The cultural construction for energy efficiency aims to create an atmosphere of energy efficiency within an institution. The energy strategy adopted by an institution can be well communicated among all kinds of departments and related person by effective measures. The mind of consuming energy is fully unified and awareness of energy efficiency can dramatically be improved by implementing the cultural construction. In addition, energy cost of the institution can also be reduced by the strategy.

For the purpose of this study, a very good method is advised here for the cultural construction, it is the ISO 50001 (Energy management systems-Requirements with guidance for use). The ISO 50001 was approved by European committee for standardization (CEN) on 25 October 2011. The standard aims to enable organizations to build the systems and processes for improving energy efficiency, use and consumption (Jovanovic & Filipovic, 2016). This standard can be introduced for all types and sizes of organizations. According to ISO (2017), the number of issued certificates for ISO 50001 in 2016 was 20,216 in the world. Relying on the support from the government, Germany reached almost 50% of the world's certifications holders. As a result, a number of achievements have been obtained in Germany, for example, large companies' energy efficiency has been improved significantly, and the awareness of energy management in Germany is much higher than before.

The implementation of ISO 50001 for MET institutions is still a new topic at a global level. The starting point of implementing ISO 50001 is the energy policy, for example, an institution can state that we commit our energy manage system to meet the requirement of ISO 50001, and we commit to raise the awareness of energy efficiency for all staff. Then building an energy management system should follow several steps including energy planning, implementation and operation, checking and management review. Especially, the phase of energy planning is one of the key elements. In energy planning, an energy review is carried out to analyze energy use and consumption, identify areas of significant energy use and consumption, and identify opportunities for improving energy performance. Then based on the results of energy review, the energy baseline, energy performance indicators, related objectives and targets, and action plans will be formulated.

4.5 Suggestions for policy making

In order to build up the systematic framework of improvement measures, some lessons from other industry such as manufacturing and construction industry were analyzed as follows.

Lessons from manufacturing industry

China is one of largest manufacturers in the world. Almost 60 percent of Chinese total primary energy is consumed by manufacturing industry (Zhao et al, 2014). Zhao et al. (2014) stated that national policy plays a very important role in energy efficiency improvement of manufacturing industry. For example, energy-conservation strategy was included into Chinese development plans and annual plans in 1981; the Energy Conversation Law was adopted by Chinese government in 1997; at the end of 1998, around 25 energy conversation and efficiency laws, regulations and nearly 100 related national standards were developed by Chinese government. Therefore since 1980s energy efficiency of manufacturing industry has been improved dramatically in China.

Lessons from construction industry

Around 20 percent of Chinese total primary energy is consumed by construction industry (NBS, 2012). Since 2000s building energy efficiency has been improved significantly in China. The factors that result in the improvement include strategies and support from central government of China, strict governance with clear responsibilities defined, a large amount of financial support, and appropriately monitoring stakeholder’s responsibilities.

Meanwhile, there are also some challenges existing in China for building energy efficiency such as local government’s regulatory and financial support are not sufficient; some implementation process for building energy efficiency measures is not effective.

Considering the lessons from manufacturing and construction industry, policy is also the cornerstone for improving MET. The four aspects of barriers identified cannot be addressed without effective policies. For example, the two subjects designed in 4.1 cannot be implemented without related supportive policies of MET institutions.

In order to achieve a good management, the commitment from top management is crucial. Furthermore, according to the bottom-up method, all measures mentioned above would not be fully and effectively implemented, if no related policy comes from competent authorities. In fact, there is only one policy document for improving MET from OET, which was adopted in 2012, and does not mention energy efficient ship operation. Therefore, there is an urgent need to adopt a policy document to improve MET for energy efficient ship operation in China.

4.6 Summary

This chapter discussed the systematic framework of improvement measures for overcoming the MET-related barriers in China. A few suggestions for making the policy document are discussed as follows: Firstly, the document should clearly define responsibilities of MET institutions; secondly, specific objectives and targets should be set according to the present situation of Chinese MET; thirdly, necessary resources should be allocated to related institutions to ensure the implementation of improvement measures. At last, some requirements or procedures for checking or auditing the progress of improving MET should be identified.

5. Assessment of Improvement measures and Continual Improvement

In order to address the barriers identified in Chapter 3 and improve MET of China for energy efficient ship operation, the framework of improvement measures was developed in the previous Chapter. Before fully implementing the above improvement measures, trials should be selected to assess the results of implementation of related measures. Considering the limitation of this study, a batch of cognition practice of Marine Engineering students of DMU is chosen to assess the workshop advised in 4.3 through online communication with educators. Furthermore, the improvement measures should be improved continually. Because some barriers may be not realized initially, and during the process of implementation of the measures, some new barriers may also appear. Therefore, the concept of continual improvement for the improvement measures framework should be considered at every moment.

5.1 Assessment of the workshop

In a batch of cognition practice, around 90 Marine Engineering students study on YUKUN vessel for one month. The students are generally divided into 4 groups, group 1 works and studies with the Second Engineer, group 2 is with the Third Engineer, group 3 is with the Forth Engineer, and group 4 is kitchen helper. The content of working and studying is changed every week. After one month, each student can get a full picture of seafarers' job. The voyage plan of each cognition practice is normally arranged as follows: in the first week the YUKUN vessel is berthed for students to know the surrounding, in the second and third week the vessel navigates and anchored for several days, the last week is berthed for examination. Therefore, the last week is selected to do the workshop. Additionally, before the workshop, some related materials are distributed to educators.

Each group is divided into 4 subgroups. Each subgroup is assigned one topic. The detail of topics and requirements is shown in the table 4.

Table 4: The topics and requirements for workshop

(Source: Author)

Topics title	Requirements for the topics
The YUKUN vessel lighting system and its energy consumption analysis	1. General introduction to the lighting system; 2. Analyzing energy consumption situation of the lighting system; 3. Discussing how to improve energy efficiency of the lighting system and possible profit.
Ship speed and main engine fuel consumption	1. General introduction to main engine and its fuel consumption; 2. Presenting the relationship between ship speed and main engine fuel consumption; 3. Discussing how to improve energy efficiency of main engine and possible profit.
Electronic supply and fuel consumption	1. General introduction to electronic supply of YUKUN vessel and its fuel consumption; 2. Presenting how to manage shaft generator and traditional diesel generators; 3. Discussing how to improve energy efficiency of electronic supply system
Cooling water system	1. General introduction to cooling water system; 2. Analyzing the key energy consumers of the cooling water system; 3. Discussing how to improve energy efficiency of cooling water system.

One group of students was chosen for this assessment. The examination for the workshop was carried out by individually oral examination. All students believed that this workshop is helpful for improving understanding of energy efficient ship operation. But some students' performance were not very good, because they had not been given related lectures on energy efficient ship operation, and teachers working on the training vessel were also lack of related knowledge.

5.2 Continual improvement to the improvement measures framework

The Plan-Do-Check-Act (PDCA) cycle is a framework for enhancing the effectiveness of measures, which is first used for quality management and proposed by an American statistician, Deming, W. E. (Zhang, 2013). The PDCA cycle is special for continuous improvement including 4 stages, which are planning stage, implementing stage, checking stage, and review stage. With the application of PDCA cycle for this study, some suggestions for continually improving the framework of possible measures are discussed as follows.

The work that has done in Chapter 2, 3 and 4 can be treated as the key part of the planning stage. The main output of planning stage is an action plan, in this study, the action plan is the improvement measures advised in the Chapter 4. In the implementing stage, the improvement measures should be carried out step by step. In the checking stage, institutions should monitor, measure and analyze the key characteristics of its operations that determine effect of MET such as employment rate, feedback from shipping companies, and feedback from students. In addition, an internal audit can be employed to ensure whether the planned measures are conformed, implemented, and maintained effectively. According to the results of checking, some corrective or preventive actions should be taken for actual and potential nonconformities. The last stage is review stage, which review the previous works that have been done in previous stages. The main output of the review stage is some decisions or actions related to changes to the improvement measures. In the other words, the output from review stage works on the planning stage to perfect the framework of improvement measures for improving MET. Therefore, the improvement of MET should be recognized as a process rather than some actions. The planning, implementing, checking and review are the key components of the process, and interdependent with each other.

The core idea of participatory design approach is to actively involve all stakeholders, such as students, seafarers, and shipping companies. Based on the PDCA cycle, the framework of improvement measures should be reviewed timely. In the phase of plan, recommendations of all stakeholders should be considered to ensure the framework meet the needs of energy efficient ship operation.

5.3 Summary

This chapter carried out an assessment of the advised workshop for cognition practice through a Chinese case, and focused on continual improvement to the improvement measures framework by introducing the PDCA cycle and participatory design approach. The result of the assessment was satisfactory. But there are still some challenges to implement the workshop very well. To overcome the challenges, the framework of improvement measures should be carried out as soon as possible. Continual improvement of the framework is significant for improving Chinese MET. The PDCA cycle and participatory design approach are extremely suitable for this issue. The principle of the two approaches should be studied deeply and be introduced for improving Chinese MET.

6. Conclusion and Recommendations

The amount of international shipping GHG emissions is expected to continue growing according to the Third IMO Greenhouse Gas Study released in 2014. It is estimated that there will be an increase between 50% and 250% in international shipping carbon dioxide emissions up to 2050, with the operational and technological improvements are being carried out. An EU study Emission Reduction Targets for International Aviation and Shipping estimated that shipping will generate 17% of global GHG by 2050, if no effective management measures will be carried out. In order to address this issue, there are already a large number of technical and operational measures for improving energy efficiency of shipping. However, implementation is a key factor affecting actual effect of these measures. Therefore, this study focuses on MET of China to enhance the process of implementation of energy efficient measures for international shipping.

Firstly, this study identified the increasing demand to MET for energy efficient ship operation from IMO framework and EU framework by literature review. The increasing demand identified is the driver for improving MET of China. Then, in order to develop measures for Chinese MET to overcome challenges from international shipping, this work identified a series of barriers existing in the MET of China by literature review, questionnaires, and online workshop. Based on the barriers, a systematic framework of improvement measures for improving MET of China was developed. In addition, in order to assess the improvement measures for cognition practice, a batch of cognition practice of DMU was selected. At last, the concept of continual improvement was highlighted, and the PDCA cycle was introduced for continually improving the framework of improvement measures. The highlights of research results are presented as follows.

a) The increasing demand to MET of China for energy efficient ship operation is mainly from development of international regulations adopted by IMO for energy efficient shipping such as EEDI and SEEMP. Especially, the SEEMP provides several best practices for energy efficient ship operation, implementation of these best practices requires MET to provide more advanced and special education and training. Furthermore, the application of new energy resources including LNG, wind power, solar power, fuel cells and batteries also brings a number of challenges for MET of China.

b) The barriers existing in the MET of China for energy efficient ship operation can be divided into 4 aspects, which are courses, pedagogy, cognition practice and cultural construction for energy efficiency. Each aspect of barriers includes 4 subgroups including human beings, finance, other resources and policy. The detail information is shown in the table 1.

c) The framework of improvement measures developed in this study includes 5 dimensions, which are courses, pedagogy, cognition practice, cultural construction and policy making. Two new subjects were designed for the dimension of courses. A systematic project was developed for improving pedagogy. The international standard ISO 50001 was introduced for cultural construction. At last, a new policy document was advised for competent authority.

d) The PDCA cycle was applied to management of the framework of improvement measures. Some suggestions for the phases of planning, implementing, checking and review were advocated for institutions.

However, the research work that has been done in this study just opened a window for Chinese MET for energy efficient ship operation. It is possible to anticipate new barriers appearing during the implementation process of improvement measures. The improvement measures advocated in this study also need to be adjusted according to the development of MET and technologies. For future research, researchers should closely follow the development of shipping industry, be led by market demand, look at

Chinese MET at an international level, and at last find more practical and effective measures to improve MET of China. For example, improving MET of China for the application of new energy sources such as LNG, wind power, and fuel cells; developing regulation framework for MET of China to achieve energy efficient ship operation.

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Appendices

Questionnaire for teachers

Date:

<table>
<tr><td>Organization</td><td></td><td>Department</td><td colspan="2"></td></tr>
<tr><td>Specialization</td><td></td><td>Professional qualifications</td><td colspan="2"></td></tr>
<tr><td>Courses</td><td colspan="4"></td></tr>
<tr><td colspan="3">Do you know the regulations for energy efficiency of shipping adopted by IMO? (e.g. EEDI, SEEMP, EEOI and DCS)</td><td colspan="2">Yes/No</td></tr>
<tr><td colspan="3">In your opinion, is the energy efficiency a very important part of the management of shipping?</td><td colspan="2">Yes/No</td></tr>
<tr><td colspan="3">In the courses you are in charge of, is there any content relating to the implementation of energy efficiency? If there is, please offer some general introduction.</td><td colspan="2"></td></tr>
<tr><td colspan="3" rowspan="2">Suggestions to improve the maritime education and training for energy efficiency of shipping in China.</td><td colspan="2">Barriers:</td></tr>
<tr><td colspan="2">Further measures:</td></tr>
</table>

Questionnaire for seafarers

Date:

<table>
<tr><td>Ship type</td><td></td><td>Academic degree</td><td></td></tr>
<tr><td>Sailing age</td><td></td><td>Professional qualifications</td><td></td></tr>
<tr><td colspan="3">Do you know the regulations for energy efficiency of shipping adopted by IMO? (e.g. EEDI, SEEMP, EEOI and DCS)</td><td>Yes/No</td></tr>
<tr><td colspan="3">In your opinion, is the energy efficiency a very important part of the management of shipping?</td><td>Yes/No</td></tr>
<tr><td colspan="3">In the education and training you have experienced, is there any content relating to the implementation of energy efficiency? If there is, please offer some general introduction.</td><td></td></tr>
<tr><td colspan="3" rowspan="2">Suggestions to improve the maritime education and training for energy efficiency of shipping in China.</td><td>Barriers:</td></tr>
<tr><td>Further measures:</td></tr>
</table>

Questionnaire for managers in MET

Date:

<table>
<tr><td>Organization</td><td></td><td>Department</td><td></td></tr>
<tr><td>Work age</td><td></td><td>Professional qualification</td><td></td></tr>
<tr><td colspan="3">Do you know the regulations for energy efficiency of shipping adopted by IMO? (e.g. EEDI, SEEMP, EEOI and DCS)</td><td>Yes/No</td></tr>
<tr><td colspan="3">In your opinion, is the energy efficiency a very important part of the management of shipping?</td><td>Yes/No</td></tr>
<tr><td colspan="3" rowspan="2">Suggestions to improve the maritime education and training for energy efficiency of shipping in China.</td><td>Barriers:</td></tr>
<tr><td>Further measures:</td></tr>
</table>

Questionnaire for companies

Date:

<table>
<tr><td>Name of company</td><td></td><td>Number of seafarers</td><td></td></tr>
<tr><td>Sailing route</td><td></td><td>Ship type</td><td></td></tr>
<tr><td colspan="3">Do you know the regulations for energy efficiency of shipping adopted by IMO? (e.g. EEDI, SEEMP, EEOI and DCS)</td><td>Yes/No</td></tr>
<tr><td colspan="3">In your opinion, is the energy efficiency a very important part of the management of shipping?</td><td>Yes/No</td></tr>
<tr><td colspan="3" rowspan="2">Suggestions to improve the maritime education and training for energy efficiency of shipping in China.</td><td>Barriers:</td></tr>
<tr><td>Further measures:</td></tr>
</table>

The record for online workshop

Date: 1 August, 2018 - 6 August, 2018

Subject	Identifying the barriers existing in MET of China for energy efficient ship operation based on the result of questionnaires and literature review		
Location	Online (Wei chat)	Question-master	Author

The procedure of workshop:

The workshop was built by Weichat software, and operated online. Firstly, the background and objectives of the research, and preliminary result of questionnaires and literature review was presented to the workshop members. 24 hours was given to the members for understanding the content of this workshop. Then, the members discussed the main aspects of the barriers and analyzed how to define the details in each aspect. At last, the members reviewed categories of the barriers, and modified some details that were not appropriate.

The decision of workshop:

The main result of the workshop is shown in the Table 1(The barriers identified and categorized by a workshop). Furthermore, some suggestions for improvement measures were also discussed in the workshop, for example, developing new subjects to cover the basic knowledge of energy efficient ship operation, improving the capacity of teachers and trainers.

Information of members			
No	Profession	Work age	Title
1	Marine Engineering	30 years	Professor, Chief Engineer
2	Marine Engineering	25 years	Professor, Chief Engineer
3	Marine Engineering	15 years	Associate Professor, Second Engineer, Vice head of office of Educational Administration
4	Marine Engineering	18 years	Associate Professor, Chief Engineer
5	Marine Engineering	10 years	Lecturer, Third Engineer
6	Navigation	20 years	Professor, Captain
7	Navigation	25 years	Professor, Captain, Vice head of office of Educational Administration
8	Navigation	20 years	Lecturer, Captain
9	Navigation	18 years	Lecturer, Captain
10	Navigation	12 years	Lecturer, Captain
11	Marine Engineering	10 years	Lecturer, Third Engineer

Figure 11: The screenshot of Wei chat on starting the workshop

(Source: Author)

Figure 12: The screenshot of Wei chat on the workshop members

(Source: Author)

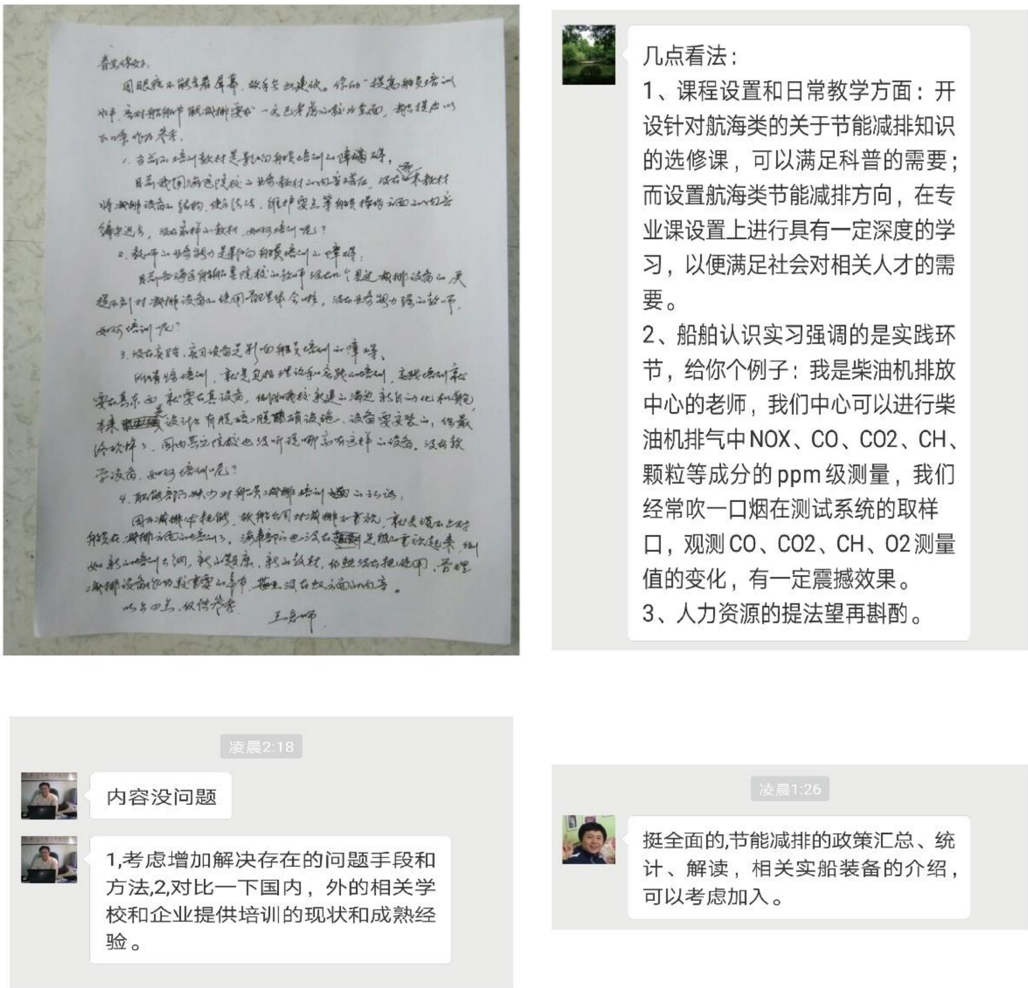

Figure 13: The examples of discussion in the online workshop

(Source: Author)

As shown in the figure 12, the picture of a paper was from Professor and Chief Engineer Wang, who is one of top persons in the MET of China. Because he had something wrong with his eyes in the period of workshop. Therefore, he wrote some suggestions on the paper, and then took a photo, and sent to the workshop. By this praiseworthy action, a conclusion can also be got that there is an urgent need to improve MET for energy efficient ship operation in China.

Table 2: The outline of Subject 1

(Source: Author)

Subject 1: The Foundation of Maritime Energy Management Total hours: 36h		
The content of teaching and related barriers	The objectives of teaching	Hours
1. Large Marine Ecosystems (LMEs) a. General introduction to LMEs b. Goods provided by LMEs c. Service provided by LMEs d. Overview of LMEs of China **Related barriers:** Lack of environmental education; Poor awareness of environmental issues	a. Understanding the notion of LME b. Remembering the full picture of LMEs at a global level c. Understanding the goods and service provided by LMEs d. Remembering the status of LMEs of China	3
2. Impacts for the LMEs a. Climate change b. Illegal, unreported and unregulated fishing (IUU fishing) c. Other human activities impacting Oceans **Related barriers:** Lack of environmental education; Poor awareness of environmental issues	a. Understanding the feature of climate change b. Understanding the effect of climate change c. Remembering the full picture of IUU fishing d. Understanding the principle of how the other human activities impacting oceans	4.5
3. Energy system a. System approach b. Energy and human beings	a. Understanding the principle of system approach b. Understanding the relationship	6

c. shipping system **Related barriers:** Poor awareness of environmental issues and its relationship with ship operation	between energy and human beings c. Understanding the elements, finality, and interrelationships of shipping system.	
4. International Maritime Organization a. General introduction to IMO b. The process of IMO regulation c. MARPOL convention d. Other regulations of IMO f. IMO framework and EU framework **Related barriers:** Poor access to regulations	a. Remembering the full picture of IMO including structure, tasks, background b. Understanding the working process for IMO to adapt regulation c. Understanding the background and content of MARPOL convention and related amendments and guidelines d. Remembering the other regulations of IMO such as STCW, MLC, SOLAS, and their relationship with energy efficiency f. Remembering the basic EU framework for shipping	9
5. Maritime economics a. General introduction to maritime economics b. Basic economic concepts	a. Understanding the relationship of world economy and international shipping b. Understanding the basic	6

c. The demand and supply of international shipping d. Maritime freight market **Related barriers:** Lack of knowledge of economics	concepts such as the law of supply and demand, elasticity, opportunity cost. c. Understanding the evolution of shipping from demand and supply sides d. Understanding the basic principle of changes to maritime freight market	
6. Science of management a. The nature of management b. The nature of organizational behavior c. Policy cycle d. Application of management for energy efficient shipping **Related barriers:** Lack of knowledge of management	a. Understanding the definition, evolution of management, especially Quinn's Competing Values Framework b. Understanding the basic principle of organizational behavior c. Understanding the basic principle of policy cycle and its application. d. Understanding the importance of management for energy efficient shipping	7.5
Requirements for the teacher charging of this subject: Background of maritime affairs, and having certificates for education and training of economics, international law, science of management, and environmental science.		

Table 3: The outline of Subject 2

(Source: Author)

Subject 2: The Technical and Operational Measures for Energy Efficient Shipping Total hours: 36h		
The content of teaching and related barriers	The objectives of teaching	Hours
1. Energy Efficiency Regulations a. The background of energy efficiency regulations b. Regulations on EEDI c. Regulations on SEEMP d. Guidelines of EEDI e. Guidelines of SEEMP and EEOI f. Guidelines of Data Collection System **Related barriers:** Lack of access to relevant regulations	a. Remembering the background of energy efficiency regulations b. Understanding regulations on EEDI and SEEMP c. Understanding the calculation of attained EEDI and EEOI d. Understanding the basic principle of SEEMP and the potential measures for ships f. Understanding the requirements of DCS	8
2. Energy Efficient Ship Design a. Basic knowledge of ship resistance b. Basic knowledge of ship propulsion c. Hull-Engine-Propeller Matching **Related barriers:** Poor access to latest technologies	a. Understanding the basic knowledge of ship resistance such as components, resources b. Understanding the key parameters of propeller, remembering different types and design of propeller	5

	c. Understanding the relationship of hull, engine and propeller, and be able to apply the knowledge for new situations	
3. Waste Heat Recovery System (WHRS) a. General introduction to WHRS b. Operation and maintenance of WHRS c. Best practices of application of WHRS **Related barriers**: Poor access to latest technologies	a. Understanding the principle of WHRS b. Understanding the key points of operation and maintenance of WHRS	3
4. Emissions Reduction Technologies a. Scrubber System b. Hull coating c. Engine Injection Tuning d. Cold ironing e. Speed Reduction f. Other measures **Related barriers:** Poor access to latest technologies	a. Understanding the types, components and operation requirements of scrubber system b. Understanding the principle of anti-fouling system, and application of hull coating c. Understanding the principle, operational requirement of engine injection tuning d. Understanding the components, operational requirements of cold ironing	9

	system e. Understanding the relationship between speed and engine power	
5. LNG as a Marine Fuel a. Introduction to LNG as a marine fuel at a global level b. The equipment for LNG as marine fuel c. The infrastructure of LNG as a marine fuel d. The logistics of LNG as a marine fuel e. The train demand for LNG as a marine fuel **Related barriers:** Poor access to latest technologies	a. Understanding the demand for LNG as a marine fuel in terms of equipment, infrastructure, logistics and training b. Understanding the present situation of application of LNG in shipping c. Understanding the key operation points for LNG as a marine fuel	7.5
6. Other Energy Resources a. Wind power b. Solar power c. Fuel cells d. Batteries **Related barriers:** Poor access to latest technologies	a. Understanding the basic principle of wind power, solar power, fuel cells and batteries for ships b. Understanding the key operational requirements of these new energy resources	3.5
Requirements for the teacher charging of this subject: Background of maritime affairs, and maritime energy management.		

The Subject 1 is designed for the second year students of university, the Subject 2 is designed for the fourth year students of university. For colleges and training center, the content can be adjusted according to the background and educated level of participants.