

AN EDUCATION DESIGN FOR ENERGY-EFFICIENT SHIP HANDLING

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Abstract

There has been an increasing interest in the energy-efficient operation of vessels. Stakeholders in the maritime industry have identified several methods of improving energy efficiency, and a large number of studies have been conducted. It has been emphasized by many that improving the energy efficiency on board vessels should include factors such as increasing awareness of the problem, knowledge skills and motivation by ensuring the availability of maritime education and training, which has to address both technical and human factor topics. The aim of the paper is to present a proposal for an educational design for energy-efficient ship operation for master mariner students. The objective has been to create a “Practicum” by using full-mission bridge simulator facilities. A full-mission simulator is an image of the world that allows the students to obtain skills through learning-by-doing in a safe environment. The course focus will be on energy efficiency, but sailing a ship is a multi-objective task – when he plans his voyage, the master must take into consideration safety, regulations, commercial interests, and finally also the energy consumption. This often results in conflicting goals and his actions must be balanced, which requires specific competence. The course is based on a combination of simulator sessions and reflection workshops, using the concept of “learning-by-doing” for the awareness training and reflective learning. Due to the safe learning environment, it is possible in a simulator to challenge the balance between safety, time and energy efficiency. Furthermore, during discussion in the reflection sessions, the students are trained in expressing and giving words to their thoughts behind their decisions, enabling them to reflect on action in

groups. The main objective of the course is to give the students the possibility to learn how different choices and actions affect the outcome.

Keywords: Maritime education, energy efficiency, simulator, awareness, the reflective practitioner

1. Introduction

Over recent decades, there has been an increasing focus on sustainable maritime transport. It has become a part of the political agenda, where regulation is used as the main driver, but due to increasing oil prices, the industry itself has also been driven towards a more energy-efficient operation of ships. The International Maritime Organization (IMO) has introduced guidelines for calculating energy efficiency during both the design [1] and the operation phase [2], and stakeholders in the maritime industry have identified several methods of improving energy efficiency, see for example the DNV GL Energy management study from 2015 [3]. This study is based on input from ship managers, owners and operators answering the key question “To actually increase energy efficiency in ship operation, what really matters?” The report showed that the companies struggle with the implementation of energy performance management and finally concluded “that people make the difference”. This conclusion was based on the fact that forty percent of the companies pointed out that lack of education and experience of crew and office staff is a primary barrier for improving the energy efficiency of ships. The study concludes that improving the energy efficiency onboard vessels must include factors such as awareness, capability and behavior.

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) [4] sets the standards of competence for seafarers internationally. The latest revision of the STCW convention and code was done in 2010 and entered into force on January 1st, 2012 [5]. One of the amendments highlighted in relation to energy-efficient operation is “New requirements for marine environment awareness training and training in leadership and teamwork”. Therefore, it must be expected that future generations of seafarers do not have a lack of education, as pointed out in the DNV – GL Management study. In a survey from 2011 of the Maritime Education and Training (MET) of maritime personnel in the selected Ship Energy Efficiency area [6] [7], the MET institutes interviewed point to simulator training as a way forward, as they use “try-observe-compare” as awareness training. Furthermore, the mind-set “better safe than sorry” is mentioned as a barrier, as among the institutions there was a lack of awareness about how energy efficiency can be achieved without compromising safety.

Onboard training may not be the best choice due to the lack of education of the higher-ranking officers, which was also pointed out in the DNV- GL survey [3].

Based on the findings from a study conducted at SIMAC in 2016, a proposal for an educational design for energy-efficient ship handling for master mariner students is presented in the present paper. The educational design is based on the concept of The Reflective Practitioner, as developed by Donald A. Schön [8]. The professional practitioner, in this case the competent captain, is expected to sail his ship - in short - as fast, as safely and as cheaply as possible in any conditions and under any circumstances. It is not possible to teach him how to do it. There is no way to describe every situation he may encounter, and so he will have to acquire the skills to judge the specific elements of any situation and apply his experience and knowledge in handling it.

The objective has been to create a “Practicum” by using the full-mission simulator facilities. The simulator provides the student with an opportunity to test the effects of his actions and observe the impact of his maneuvers on, for example, the energy consumption in the specific situation. A full-mission simulator is an image of the world that allows the students to obtain skills through learning-by-doing in a safe environment. The course combines simulator sessions with instructions and knowledge sharing, which will provide the students with the opportunity to acquire skills in praxis and reflect-on-action.

2. Requirements for Energy Efficiency Training

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) [4] sets the standard for the mandatory minimum requirements for certification of officers in charge of a navigational watch on ships of 500 gross tonnage or more. In the latest revision of the convention, which entered into force in 2012 [5], the amendment included requirements of *knowledge and ability to apply effective resource management* and *obtaining and maintaining situation awareness*. This amendment has been highlighted as one of the more significant changes. In addition, other smaller adjustments have been made that may affect the energy-efficient training. In Chapter II of the convention, the minimum requirements for knowledge, understanding and proficiency are described. The requirements the officer has to comply with in regard to pollution prevention can be seen in Table 1. The third column of the table describes methods for demonstrating competence - added in the latest amendment is the acceptance of approved training as a method for demonstrating competence. It can be seen that approved training in an academy and not only onboard a ship is now possible, making room for a more controlled learning environment. The

quality of onboard training will depend on the competence and motivation of the crew and may not be the best solution. This is also mentioned by DNV GL in their energy management study [3], see Section 1.

| Competence | Knowledge, understanding and proficiency | Methods for demonstrating competence | Criteria for evaluating competence |
|--|---|--|---|
| Ensure compliance with pollution prevention requirements | Prevention of pollution of the marine environment and anti-pollution procedures. Knowledge of the precautions to be taken to prevent pollution of the marine environment. Anti-pollution procedures and all associated equipment <i>Importance of proactive measures to protect the marine environment</i> | Examination and assessment of evidence obtained from one or more of the following: .1 approved in-service experience .2 approved training ship experience .3 <i>approved training</i> | Procedures for monitoring shipboard operations and ensuring compliance with MARPOL requirements are fully observed <i>Actions to ensure that a positive environmental reputation is maintained</i> |

Table 1 Minimum requirements for knowledge, understanding and proficiency. STCW [5].

Text in italics are amendments in the latest version of the convention.

3. Theory

The educational design is inspired by Donald Schön's concept of The Reflective Practitioner [8]. In his books, Donald Schön discusses how knowledge and professionalism is perceived as either technical rational, specialized, firmly bounded, scientific and standardized or on the other hand as an artistic competence to make sense of complexity. Schön's objective is to find a way to educate for professional artistry. He takes the stance that the professional practitioner deals with unique cases which cannot be handled by simply applying one of the rules from the book, and that the competence shown by professional practitioners in unique and maybe conflicted situations is the artistry or the knowing-in-action, which is the hallmark of the practitioner.

Professional knowledge is formed of three different elements and is placed in a hierarchy by Edgar Schein [9], whom Schön refers to as he makes a distinction between basic science, applied science and technical skills and states that professional knowledge cannot be acquired solely through theoretical teaching [8]. Professional knowledge can be viewed in different ways. It may be the knowledge of facts, rules and procedures to solve routine problems, or it may be a way of thinking which gives the right answer to a specific case, and finally it may be the kind of reflection-in-action in which practitioners sometimes make sense of uncertain, unique or conflicting situations of practice [10]. Theories, rules and procedures may be taught in classrooms, but the practitioners' competence can only be obtained through practicing the performance of them. According to Schön, practitioners have to solve problems in the

indeterminate zones of practice, where they face "... uncertainty, uniqueness and value conflict which escape the canons of technical rationality" [10]. To do this calls for a high degree of competence, or even artistry. In his work, Schön is inspired by John Dewey [11], who saw "learning-by-doing" as the primary way to acquire skills, as the practitioner cannot be taught, but has to "see for himself". Reflection-in-action is a key term in Schön's theory and refers to the idea that practitioners "... reflect on practice while they are in the midst of it" [8]. When solving a complex problem, practitioners draw on theory as well as experience. It could seem that they are seeking a solution through trial and error, "But the trails are not randomly related to one another; reflection on each trail and its result sets the stage for the next trail" [10].

To create room for reflection and to complement the theoretical and technical rational teaching, Schön suggests a practicum as a setting for the students to learn in practice. A practicum opens the opportunity for the students to try out knowledge and techniques learned in the classroom. "They learn by undertaking projects that simulate and simplify practice; or they take on real-world projects under close supervision. The practicum is a virtual world, relatively free of the pressures, distractions and risks of the real one, to which nevertheless, it refers" [10]. As the student now learns by doing, the teacher's role changes from teaching to coaching. "Most practicums involve groups of students who are often as important to one another as the coach. Sometimes they play the coach's role. And it is through the medium of the group that a student can immerse himself in the works of the practicum, "... learning new habits of thought and action" [10]. After the workshops, the students get the opportunity to discuss their understanding of the task and outcome and to share experiences of the different means and methods employed to obtain the results wanted.

The individual student reflects-in-action while solving problems, applying previous experience and the theoretical knowledge acquired in the classroom, or maybe working with other students on a specific task, trying out techniques or standards to handle complex situations. Subsequently, the students meet with the coach in a reciprocal reflection-on-action.

The Reflective Practicum is developed to take reflection to a higher level. In the reflective practicum, the coach offers a reciprocal reflective dialog and encourages the student to reflect-on-action. Students must be ready to engage in a discussion, to openly share doubts and to give and receive critique, as "A reflective practicum must include values and norms conducive to reciprocal, public reflection on understandings and feelings usually kept private and tacit" [10]. Reflection-on-action has taken reflection "a step up". Schön exemplifies this by using a ladder metaphor and describes the rungs of the ladder: the first step being reflection-in-action, which is done while performing the task, and following this, the second step, reflection-on-action, is a

description of what is done and why, i.e. the thoughts behind the chosen action and the evaluation of the results. This reflection is reciprocal and the coach's questions, advice, or criticism may be part of it. This may also be described as a first and second order reflection. One step further up the ladder leads to reflection on the process, and the last step on the ladder is a reflection on the dialog itself; reflection on the reflections [10]. In the reflective practicum, learning is acquired moving up and down the ladder as reflection follows action and new action is undertaken following reflection, and so forth.

The work of a reflective practicum takes time, as it takes time to shift back and forth between reflection-on-action and reflection-in-action, sometimes even several months, but a practicum may be incorporated in the educational curriculum of a professional school.

4. Design of the Course

The crew onboard the ship plays a very important part with regard to energy-efficient ship handling; it is they who make the daily operational decisions, such as route, speed and engine settings - all parameters that influence the energy consumption. For improving the knowledge and understanding the problem, the present course has been developed following the theory of The Reflective Practicum, and so it is meant to be a part of the basic training to become a master mariner.

The aim of the course is to increase the awareness, knowledge, skills and motivation by the education and training of coming officers for energy-efficient ship handling. The focus will be on energy efficiency, but this is only one parameter among many others, such as the environmental conditions, the traffic intensity and the expected weather conditions, which the master mariner, being a professional practitioner, must take into consideration when he plans and conducts his voyage. The master has to consider multiple objects such as safety, regulations, commercial interests, and finally also the energy consumption. These often result in conflicting goals and his actions must be balanced, which requires specific competence.

The course is based on a combination of simulator sessions and reflection workshops, using the concept of “learning-by-doing” for the awareness training and reflective learning. Due to the safe learning environment, in a simulator it is possible to challenge the balance between safety, time and energy efficiency. Furthermore, during discussion in the reflection sessions, the students are trained to express and give words to their thoughts behind their decisions (reflection-in-action), enabling them to reflect-on-action in groups. The main objective of the course is to give the students the possibility to learn how different choices and actions affect the outcome.

The learning program is divided into six phases. Each phase is described by learning objectives, and a description of how these objectives are achieved during the specific session. The students are part of a training group of about eight students; the students are in command, officer on watch (OOW), one at a time, but meet during the workshops. Each phase ends with a small session, where the student (the officer on watch) together with the coach reflect on the performed voyage, thus following Schön's ladder metaphor, moving up and down. It is expected that the students have basic knowledge about energy efficiency management before attending the course. Basic theory, and navigational and ship handling knowledge, are a prerequisite and are acquired through the curriculum for master mariners.

Phase 1: Simulator - Familiarization

Initially the students must familiarize themselves with the route, the vessel and its maneuverability. The goal here is to make the simulator training realistic.

Phase 2: Simulator – Baseline

In order to establish a basis for reflection and discussion, the route is sailed three times. A short introduction to the use of a fuel monitor installed on the bridge is given to the students, they are encouraged to use it as a tool and the “learning-by-doing” concept (try-observe-compare) is introduced. The performance and awareness may be influenced by previously acquired experiences, like for example onboard training during their apprenticeship.

Phase 3: Workshop – Knowledge sharing

The students are presented with information about the voyage and the energy consumption for the first three voyages performed during phase 2, in the form of diagrams and data. The purpose of the session is knowledge sharing – the students will be encouraged to compare, reflect and discuss with each other their way of conducting the voyage. The intention is to make room for reflection-on-action in a group to improve the learning through reciprocal reflections, see Section 3.

Phase 4: Simulator

After the workshop performed in phase 3, the voyage will be conducted again. Data on the voyage and on energy consumption are collected and used at the end of the session in the reflection on the session with the coach, when the benefit from exchange of experience and the knowledge sharing between the students are considered and discussed.

Phase 5: Simulator - Complex navigation

The voyage is conducted again with increased complexity - the visibility is reduced and the traffic intensity is increased. During this phase, the student must take into account new and additional environmental elements, forcing him to make decisions considering conflicting

requirements. This will make room for reflection (reflection-in-action) on how changes in condition will affect his actions/decisions, and how the balance between safety and energy efficiency may have changed.

Phase 6: Knowledge sharing

The students are presented with data about all performed voyages. They are encouraged to reflect and discuss the course progress with each other. During this session, the students are trained to express and give words to their thoughts behind the decisions taken. They not only make reflection-on-action in a group, but also reflection on the reflections.

5. Discussion

Increase of awareness is one of the focal points when it comes to energy efficiency, but to be aware requires the competence to identify what to be aware of. Lack of experience and education has been identified as a primary barrier for improving the energy efficiency of ships [3]. Before the 2010 amendments to the STCW convention [5], training in energy efficiency was an objective for onboard training, but as the older, experienced officers onboard had not received education on the subject, they too were trained onboard [7]. The level of skills of the experienced onboard crew may well be low with regard to energy efficiency, and the learning and training of the cadets in the subject would therefore be arbitrary. The described educational design is performed ashore in a simulator. This provides the opportunity to control the process, combining the knowledge obtained during apprenticeship (onboard training) with theoretical knowledge/basic science. The students will be trained for mastering multi-objective conditions - safety, regulations, commercial interests, energy efficiency – forcing them to make decisions based on conflicting conditions. There is no right and wrong; the balance between the multiple objectives are individual, and so the course focuses on the reflection-on-action. If the students are to reflect on their action in a group, they must be trained to express and give words to their thoughts behind their decisions - they need a vocabulary to describe their actions, which together with competence are the most important skills for them to achieve. The vocabulary gives them the possibility to discuss and argue their choice of action, and thereby assessment of the skills acquired becomes possible. Many experienced officers lack this vocabulary, which keeps them from being able to share their knowledge with both colleges and cadets onboard. The reflection-on-action in groups is a centerpiece to the educational design, but it has to be acknowledged that it is a vulnerable situation. The student has to open up to the other participants in the group, not only to give word to their actions, but also to learn from each other's actions. This requires trust between the participants, and if this is not obtained, the

reflection session might be without value. This is why a smaller, more intimate group of only eight participants is suggested.

In order for the students to enter the practicum and to challenge a multi-objective condition, the students need some experience – they must be able to understand the consequences of their actions – and therefore the course has to be placed in the final part of the education.

The DNV-GL survey touches on the subject of the education of the land-based office staff. This course will give the participants – who will become officers on board - the skill and competence for making energy efficiency an objective in the comprehension of the situation. But the land-based staff have a large influence on the operation of the vessel, with requirements from the owner and charterer adding to the complexity of the situation and possibly representing additional conflicting goals. The land-based staff might not understand the complex situation the crew experience on board. The company's culture has to support the change, and both land-based staff and experienced crew need to acquire the awareness and capability to prioritize and support energy-efficient operation- This is why in-service training has to be addressed at a later stage.

6. Conclusions

The described education design ensures training of awareness, capability and behavior. Through the training of reflection-on-action, the student achieves the competence to knowledge share and it enables him to reflect-in-action. By analyzing and reflecting on consumption data, the students become aware of how their choice of action influences the outcome, how their giving priority to one requirement over another affects the others. This visualization is possible in a controlled and safe learning room, as offered in the design, where it is possible to test different solutions without compromising the safety of the vessel and to compare results. The achieved vocabulary makes the future officer able to share knowledge obtained by experience to future students during their apprenticeship, which will add to the capacity building both in companies and in the education system with regard to energy-efficient operation of vessels.

7. Acknowledgements

The authors would like to acknowledge funding support from the Danish Maritime Fund (2014-089; SDU, Situation Awareness) and Innovation Fund Denmark (File no. 155-2014-10).

This study was conducted during a project carried out under Blue INNOship – a Danish societal partnership focusing on creating growth and employment in the Blue Denmark through the development of green and energy-efficient solutions.

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