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The effectiveness of engine room simulator (ERS) as a learning tool in maritime education and training (MET)

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WORLD MARITIME UNIVERSITY
Malmö, Sweden

THE EFFECTIVENESS OF ENGINE ROOM SIMULATOR (ERS) AS A LEARNING TOOL IN MARITIME EDUCATION & TRAINING (MET)

By

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A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of

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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.

Signature of author: ………………………………

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Abstract

Title of Dissertation: **The effectiveness of Engine Room Simulator (ERS) as a learning tool in Maritime Education & Training (MET)**

Degree: **Master of Science**

Although automation helps seafarers to perform various tasks and it reduces the seafarers' workload significantly, training and understanding of working principles are equally important in order to ensure a high degree of safety environment in the workplace. Complicated propulsion systems lead to main engine failures and resulting in accidents. The right training approach is very crucial to ensure the effectiveness of the learning process, and it should come with the right method of evaluation, to ensure that the intended learning outcomes have been met by the trainees. It is proven that having training in ERS is useful as it provides a realistic training platform and extensive practical training to develop excellent operators in a highly automated environment. Furthermore, the ERS has a high potential to facilitate the acquisition of digital skills and other seafaring-related skills in preparing the seafarers to embrace digitalisation and technological advancement.

However, there is a lack of pedagogical understanding and approach necessary for an ERS trainers due to inadequate research on ERS compared to bridge-navigation simulators.

This multiple case study approach explores the in-depth reality and contemporary issues from multiple perspectives, namely, MET experts, seafarers, simulator manufacturers and maritime administrators. The findings from this study are analysed and discussed. Recommendations on key considerations to improve ERS usage as a learning tool are formulated in this study.

Keywords: Engine-Room Simulator, ERS, simulator-based training, Maritime Education and Training, MET, Maritime Simulator, Marine Engineer, Quality Standard Systems, QSS, Certificate of Competency, COC, and IMO Model Course.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ALAM: Akademi Laut Malaysia

AR: Augmented Reality

ARPA: Automatic Radar Plotting Aid

BT: Bloom’s Taxonomy

CBT: Computer-Based Training

CDD: Curriculum Design and Development

COC: Certificate of Competency

ECDIS: Electronic Chart Display and Information System

ECR: Engine Control Room

ER: Engine-Room

FM: Full-Mission

ICERS: International Conference on ERS

ILO: Intended Learning Outcome

IMC: IMO Model Course

ISO: International Organization for Standardization

MA: Maritime Administration

MARPOL: International Convention for the Prevention of Pollution from Ships

ME: Main Engine

MET: Maritime Education and Training

METI: MET Institution

QSS: Quality Standards System

RO: Recognised Organisation

SoC: Statement of Compliance

SRL: Self-Regulated Learning

STCW: International Convention on Standards of Training, Certification and Watchkeeping

TLA: Teaching and Learning Activity

TNA: Training Needs Analysis

UK: United Kingdoms

USA: United States of America

VR: Virtual Reality

ZPD: Zone of Proximal Development

CHAPTER I

1. General Introduction

1.1 Engine-Room Simulator background

1.2 Problem statement

1.3 Aims, objectives and research question

1.4 Research methodology and outlines

In section 1.1, the background of ERS is introduced, which helps the readers to visualise the evolvement of ERS and understand the necessity to conduct this research

Section 1.2 provides problem statements which are the areas of concerns of the researcher.

Section 1.3 explains the aims and objectives of conducting this research. The research questions are formulated in this section, and they help the readers to appreciate the direction of this research.

Lastly, section 1.4 introduces the general research methodology that will be used in the study.

1.1 Engine-Room Simulator Background

The integration of the simulators in the Maritime Education and Training (MET) curricula has been established or a few decades. Originally, simulator-based training was implemented with the main aim of developing navigational skills such as passage preparation and collaboration between the master and pilot. Simulators are used today in many areas of the maritime industry, including offshore operations training on warships and oil rigs, bridge operations, cargo handling, engine control, crane operations, towing as well as anchor handling (Hanzu-Pazara et al., 2008). The simulator is defined as a presentation of a real situation, by-products of mechanical, electro-mechanical or computer devices. The main reasons why Engine-Room Simulator (ERS) is employed in MET are due to the high price of the original equipment and the inability to access the real equipment to perform the training or research in a safe manner (Stetsenko & Stetsenko, 2019). Many forms of training that are not feasible for safety purposes to be replicated in the actual situation, can be performed in ERS, for example;

- Main Engine (ME) slowdown and shutdown functions
- Loss of power
- Equipment malfunction
- Fire and explosion

Having said that, ERS is perceived as the safest and least expensive training tool and yet is effective and practical (Tsoukalas, Papachristos, Tsoumas, & Mattheu, 2008).

In the current industrial practice, the International Conference on ERS (ICERS) plays a significant role in determining the industrial standard of ERS. As a result, class-approved simulators have become more stringent. For instance, ERS should be able to indicate the emissions quality of the engine in compliance with MARPOL Annex VI (Kluj, 2012).

The features of ERS are evolving. Initially, it started with 2D simulators, followed by 3D, and the latest features are augmented reality (AR) and virtual reality (VR). Each layout offers pros and cons. Due to the simple layout and easy to understand, a 2D simulator is handy for beginner level and suitable for operational procedures training. The 3D simulator is more dynamic and realistic, which gives greater experience and understanding. However, it demands more attention, particularly during system familiarisation (Kluj, 2017).

1.2 Problem Statement

Despite all the success stories of ERS, there are still flaws which require topmost attention. The concerned area that has been identified is the lack of pedagogical understanding and approach, which is important for an ERS trainer. This could happen due to lack of research in this area. Comparatively, pedagogical researches on navigation-bridge simulators are abundant. One of the critiques based on the studies of Norcontrol PPT 2000 ERS was that pedagogical theories are not taken into consideration while the manufacturers develop the

ERS (Tsoukalas et al., 2008). Although the international convention of Standards on Training, Certification and Watchkeeping (STCW), has set the guideline that the maritime simulator must have an appropriate level of realism (International Maritime Organization [IMO], 2017), realism and pedagogy are two different issues. The two issues are equally important for a trainer to be able to adapt to during the ERS training.

The Model Course 6.10 of Train the Simulator Trainer and Assessor, has briefly described criteria for a simulator trainer;

- attitude towards teaching
- operational experience/familiarisation
- technical/subject-related knowledge
- pedagogy
- establishing trust

(IMO, 2012)

According to Bakalov (2019), in ERS exercises involving troubleshooting and fixing malfunctions, the options for problem-solving are limited. Therefore, the trainer plays a significant role in designing the exercises, and useful approaches in explaining them to the trainees. Exploring the skills required for a good quality ERS trainer is one of the aims of this research.

1.3 Aims, objectives and research questions

The research objectives focus on the following goals:

a) To investigate the effectiveness of ERS as learning and tool through various viewpoints and perspectives.
b) To identify the competency standards that the trainers should have in order to ensure the effectiveness of training and assessment.
c) To recommend the best practices in designing and developing training via ERS.

The implication of this research is to enhance the quality of learning and assessment by using ERS in MET, and this will result in producing highly competent seafarers. This research will give benefits as a reference to the current application of ERS as well as being a benchmark for future improvement and development.

The following research questions had been formulated in order to meet the objectives of the research:

RQ1: What are the legal and learning frameworks that are currently available to ensure the effectiveness of ERS as a learning and assessment tool?

RQ2: How effective is the current practice and usage of ERS in MET, as a learning tool from the viewpoint of various stakeholders?

RQ3: What are the challenges that various parties encounter that in regards to ERS?

RQ4: How can the usage of ERS as a learning tool to be effectively optimised?

1.4 Research methodology and outlines

To accomplish the research objectives, the study was undertaken from legal (governance), pedagogical and practical viewpoints.

The research methodology was structured into two elements. In Chapter 2, the first element was an extensive literature review, combining all relevant materials related to the ERS. More relevant information was gathered during the MET specialisation studies, through various subjects, including insights from the in-house lecturers and visiting lecturers. The aim of this method was to answer RQ1 and to give preliminary knowledge before the researcher proceeds to the next approach.

The second method is a qualitative method, which used semi-structured and in-depth interview methods in data collection. The approach is further explained in detail in Chapter 3. The aims of this approach were to answer RQ2 and RQ3 as well as to elaborates the reality of ERS application in MET domains.

In Chapter 5, the results were analysed and discussed by combining all the findings from the previous studies in order to answer RQ4.

CHAPTER II

2. Legal and theoretical frameworks

2.1 The legal framework of the ERS usage

2.1.1 ERS reference under STCW

2.1.2 Trainers and assessors' qualification

2.1.3 Quality Standards System for compliance of ERS

2.1.4 ERS reference other governing bodies

The purpose of this section is to review the international governance and legal framework of the MET that is applicable to the usage of the ERS, which may become a catalyst or limitation to the effectiveness of ERS as a training tool.

Section 2.1.1 guides the readers to understand the mechanism of the STCW and its application to ERS. This section also presents the compulsory performance standards that are regulated under the STCW, as well as the guidelines of ERS capabilities, to uphold the quality of ERS.

Section of 2.1.2 gives an idea of how STCW governs the qualifications of trainers and assessors, and this underpinning knowledge will be the basis for the researcher to investigate further during the empirical research.

The Quality Standards System in section 2.1.3 is the mechanism under the STCW that is used by the maritime administrations to ensure compliance with the treaty. In this section, the processes are extensively elaborated to guide the readers on how the IMO instruments are used to govern the quality of MET, especially ERS.

Lastly, section 2.1.4 provides information on other private entities that help the maritime administration in governing the technical aspects of the ERS. This section also helps the readers to appreciate various classifications of ERS under Recognised Organisations, which will be used as determining factors of teaching, learning and assessment activities.

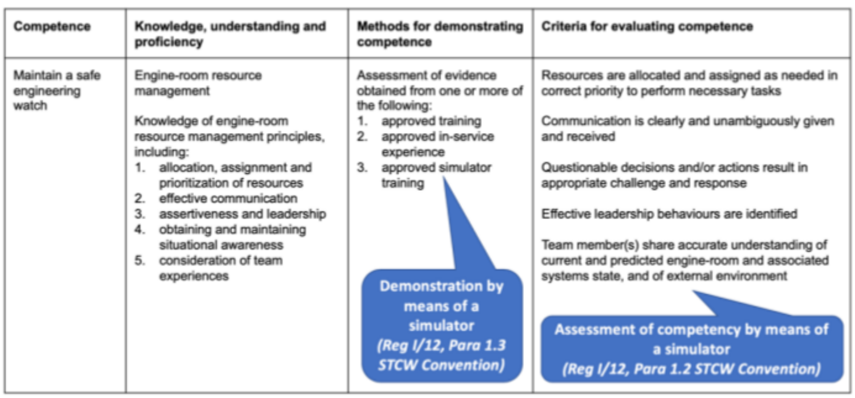
2.1.1 ERS reference under STCW

The only international legal instrument that comprehensively spells out the competences standards for seafarers is the STCW Convention. The STCW Convention was adopted in 1978 and has gone through two significant revisions in 1995 and 2010.

Under the STCW, the usage of simulators falls under Regulation I/12. It is mentioned that the provisions are applied to all mandatory simulator-based training. As of now, the only mandatory simulator training under the STCW is radar, Automatic Radar Plotting Aid (ARPA) and Electronic Chart Display and Information System (ECDIS). However, it is also stated that the provisions are applied to any simulator-based assessments and demonstrations which are required by Part A of the STCW Code (Figure 1).

Figure 1

Usage of ERS in the STCW Code



Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
Maintain a safe engineering watch	Engine-room resource management Knowledge of engine-room resource management principles, including: 1. allocation, assignment and prioritization of resources 2. effective communication 3. assertiveness and leadership 4. obtaining and maintaining situational awareness 5. consideration of team experiences	Assessment of evidence obtained from one or more of the following: 1. approved training 2. approved in-service experience 3. approved simulator training	Resources are allocated and assigned as needed in correct priority to perform necessary tasks Communication is clearly and unambiguously given and received Questionable decisions and/or actions result in appropriate challenge and response Effective leadership behaviours are identified Team member(s) share accurate understanding of current and predicted engine-room and associated systems state, and of external environment

Note. Adapted from *STCW: Including 2010 manila amendments : STCW convention and STCW code* by International Maritime Organization, 2017, IMO Publication. Copyright 2017 by IMO Publication.

In MET, ERS is optional. However, for the benefit of quality education, if any METI intends to use ERS as a training and assessment tools for the STCW certification purposes, it has to comply with all requirements in section A-I/12 and be approved by the MA through a Quality Standards System (QSS) mechanism, which will be explained later.

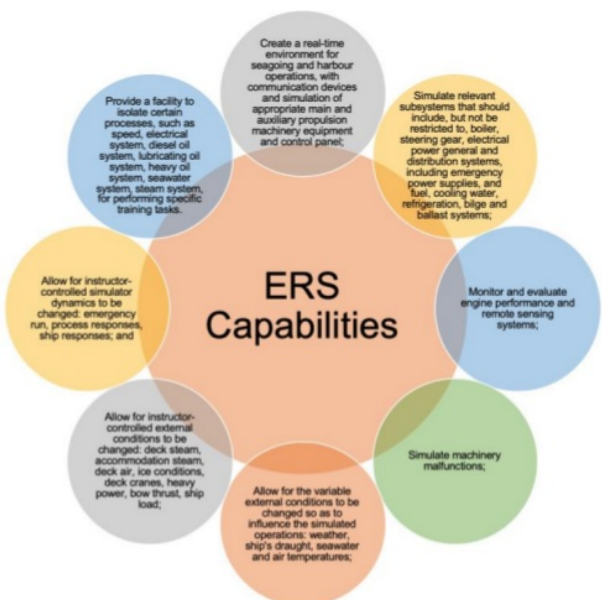
The general performance standards for using a simulator as a training and assessment tool are stipulated under Part 1, section A-I/12 of the STCW Code. In summary for Part 1, the simulator should fit its purposes, have an adequate level of realism, and be accessible for the trainer and assessor to control, including monitoring and recording the simulation for training and assessment.

Part 2 consists of other provisions, such as training objectives, training and assessment procedures, and qualifications of trainers and assessors. The STCW Convention states that briefing, planning, familiarisation, monitoring, and debriefing should be incorporated in any simulator-based exercise. This also emphasises the importance of teacher instruction and exercise prompts during the evaluation and use of peer assessment techniques during the debriefing process. The simulator exercises must be planned and reviewed by the simulator instructor to ensure that they are appropriate for the specified training goals.

Under the same section of performance standards, there are additional mandatory standards for ARPA and radar simulation. However, there are no obligatory features for ERS. Only guidelines for ERS features are given under section B-I/12 (Figure 2).

Figure 2

The guidelines for ERS capabilities



Note. Adapted from *STCW: Including 2010 manila amendments : STCW convention and STCW code* by International Maritime Organization, 2017, IMO Publication. Copyright 2017 by IMO Publication.

2.1.2 Trainers and assessors' qualifications

The STCW sets the requirement for training and assessment under Regulation I/6 and its family (Section A-I/6 and Section B-I/6 of the STCW Code). One of the vital points is that instructors, supervisors and assessors need to be qualified by the State. Those persons are called Subject Matter Experts (SME) and have a full understanding of the learning objectives and have received the necessary pedagogical skills training. They are also involved in developing and designing curricula in reference to the STCW. However, the IMO only provides recommendations for pedagogic training for those SMEs through IMO Model Courses (IMCs), rather than mandatory provisions. The IMCs are;

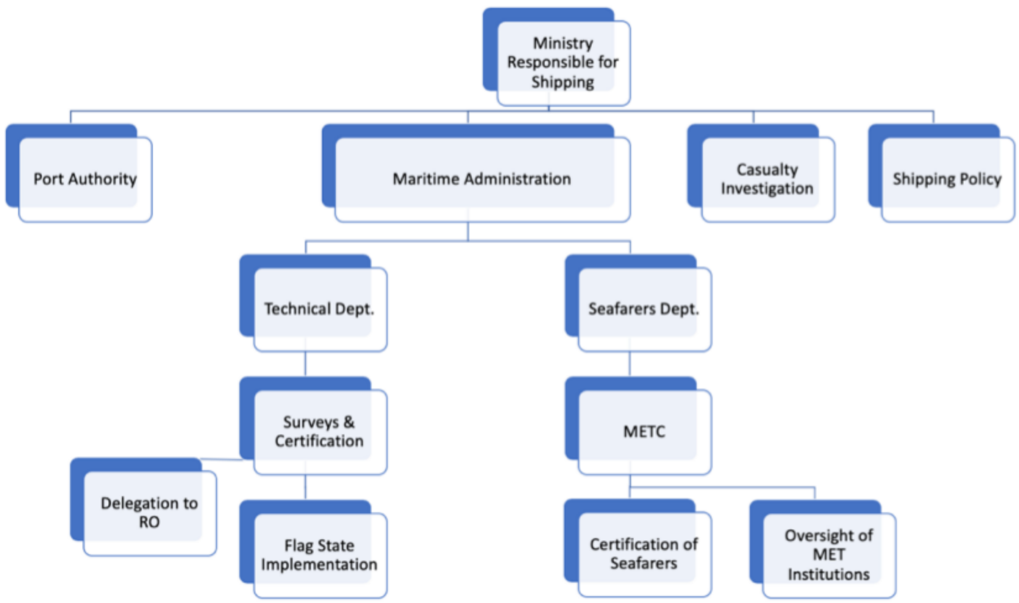
- Training Course for Instructors (6.09),
- Assessment, Examination and Certification of Seafarers and (3.12),
- Train the Simulator Trainer and Assessor (6.10)

2.1.3 Quality Standards System for compliance of ERS

Each party to the STCW convention has an obligation to ensure compliance. All the MET institutions (METIs) are governed by the maritime administration (MA) of that State for the quality control of the training and certifications. Typically, under the Seafarer Department, the Maritime Education, Training and Certification (METC) unit is formed to oversee the activities of METIs (Mukherjee & Brownrigg, 2013) (Figure 3).

Figure 3

The model organisational structure for the administration of maritime affairs

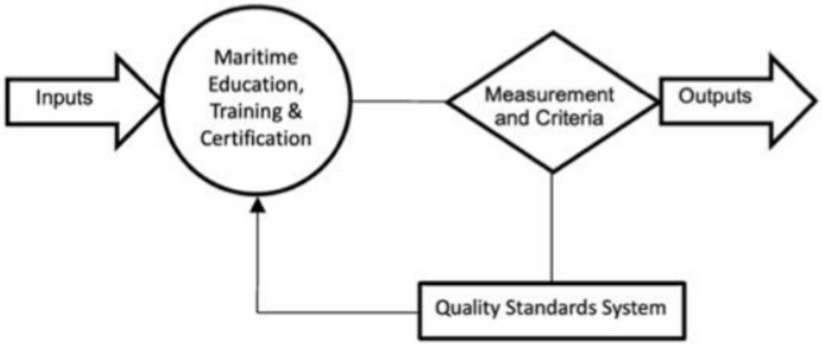


Note. Adapted from *Farthing on international shipping by* P. Mukherjee, & M. Brownrigg, 2013, Springer. Copyright 2013 by Springer.

It is the duty of an MA to implement the monitoring, control, and communication through the QSS mechanism. The MA can self-develop its QSS models, or it can use other existing international or national models. The most well-known international models for MA are the International Organization for Standardization (ISO) and other recognised organisations (RO) such as classification societies (Tuljak-Suban & Suban, 2013). The functions of QSS as a feedback loop to the MET and certification system (Figure 4) are defined in Regulation I/8 of the STCW Convention, 1978, as amended and its code in Section A-I/8.

Figure 4

QSS as a feedback loop for the continuous growth of quality



Note. Adapted from "*Quality standards implementation in maritime education and training institutions*" by D. Tuljak-Suban, & V. Suban, 2013, Fuzzy assessment, Transport Problems, 8, 63-72. Copyright 2013 by University of Ljubljana, Faculty of Maritime Studies and Transport. Copyright 2013 by University of Ljubjlana.

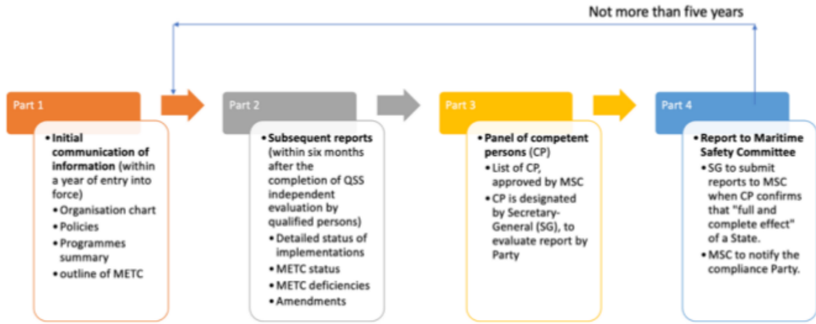
The recommendation guidelines are elaborated in Section B-I/8 of the STCW Code. The concern areas of QSS in METC are;

- all training
- assessment of competence
- certification
- endorsement and revalidation activities
- the instructors and assessors' qualification and experience

Despite all that, the MA also should establish a mechanism for internal quality assurance, and let the external qualified persons perform a periodical assessment of the QSS system. Communication concerning the implementation and amendments is established with the Secretary-General of IMO through the format specified in section A-I/7 of the STCW Code. As a result, other states may know the status of implementation of the party (White List), which will ease the issuance of recognition certificates as defined in Regulation I/10 of the STCW Convention (Figure 5).

Figure 5

Communication flow of QSS status

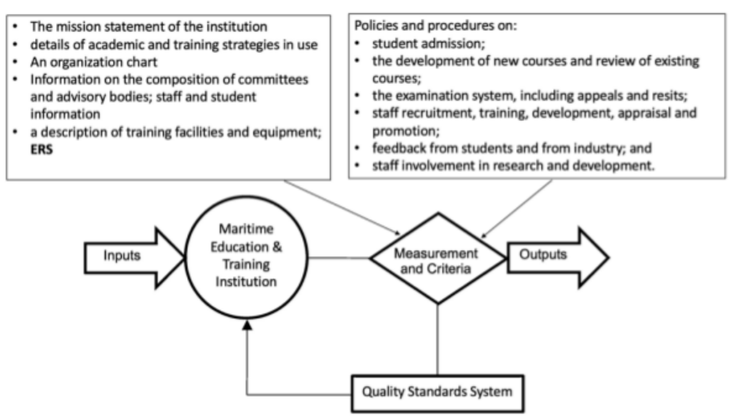


Note. Adapted from *STCW: Including 2010 manila amendments : STCW convention and STCW code* by International Maritime Organization, 2017, IMO Publication. Copyright 2017 by IMO Publication.

The METIs may establish the QSS as in Section B-I/8, paragraph 3 of the STCW Code and subject to verification by the MA. This is how the MA ensures that there is no substandard quality of training and education that being offered by the METIs by monitoring the whole spectrum of the management system (Figure 6).

Figure 6

Independent evaluation criterion for METI



Note. Adapted from *STCW: Including 2010 manila amendments : STCW convention and STCW code* by International Maritime Organization, 2017, IMO Publication. Copyright 2017 by IMO Publication.

However, the governance by MA through QSS aims to approach the systems, policies, organisational structures, and documentation. Therefore, it does not need to result in high quality of products. Often mistakes are caused by system failures, rather than the human element. There are many cases wherein the organisation has complied with the QSS, but offers low-quality products (Rasmussen, 2016).

2.1.4 ERS reference under other governing bodies

The STCW states that all the marine simulators which are used for the STCW certification purposes should obtain approval from the MA. The MA has to ensure the simulator has complied with the Regulation I/12 of the STCW. The first step that should be taken by the METI is to ensure that the ERS model has been recognised by any RO. The most well-known RO in providing recognition to simulator manufacturers is DNV-GL. A Statement of Compliance (SoC) will be issued to any manufacturer that produces the an acceptable ERS. The ClassNK uses a different term for the same purpose, which is called as Statement of Product Quality (SoPQ)(ClassNK, 2019). Apart from that, DNV-GL also offers verification of the simulator installation, simulator-based training and assessment, and the eligibility of the trainers and assessors. After the verification process, the DNV-GL will issue a Product Certificate, which eases the approval process by the MA, and places the METI as a reputable training provider at the international level. The accreditation validity is five years and is subject to an annual audit.

The DNV-GL classifies ERS based on the limitations of the tasks (DNV GL, 2019) (Table 1). A different function area of ERS has suitability for different teaching, learning and assessment of learning activities, which will be discussed further in the next section. For an easy reference, the classification of ERS will be categorised according to DNV GL Simulator Class in this research (Figure 7) (Wärtsilä, 2020).

Table 1

The ERS Function Area

Simulator class	*Description*
Class A (ENG)	A full mission simulator capable of simulating all machinery operations in engine control room and machinery spaces, by the use of the simulated operational panels in machinery spaces.
Class B (ENG)	A multi task simulator capable of simulating several machinery operations in engine control room and machinery spaces, but with limited use of the simulated operational panels in machinery spaces.
Class C (ENG)	A limited task simulator capable of simulating some machinery operations in engine control room for procedural training.
Class S (ENG)	A special tasks simulator capable of simulating operation and/or maintenance of particular machinery equipment, and/or defined engineering scenarios.

Note. From *DNVGL-ST-0033: Maritime simulator systems* by DNV GL (https://rules.dnvgl.com/docs/pdf/DNVGL/ST/2017-03/DNVGL-ST-0033.pdf). Copyright 2019 by DNVGL.

Figure 7

ERS Categories According to DNV GL Classification

Note. Adapted from *Wärtsilä simulation and training solutions* by Wärtsilä (https://www.wartsila.com/marine/voyage/simulation-and-training). Copyright 2020 by Wärtsilä.

SECTION SUMMARY

Overall, the sections above have explained that the mechanisms used by governing bodies to ensure the usage of ERS in maritime education is at the highest practicable standard.

Regulation I/12 STCW is proof that the mechanism for regulating the usage of simulators via STCW exists. Based on STCW, ERS is an optional learning tool. However, if the ERS is used for demonstrating competence, there are specific criteria that ERS has to follow. It can be concluded that the regulations for trainer and assessor qualification are quite loose, and it seems that flexibility is given to suit the national setting and education system of the respective country. The IMO has also published various IMCs, as guidelines for all course developers in helping them create their training programmes according to the national setting. This section also explained the process of QSS in ensuring the compliance with the STCW, and how ROs play their parts in helping MA to ensure the compliance.

In conclusion, the existing legal frameworks on ERS are quite comprehensive and may improve the effectiveness of ERS usage. However, the absence of ERS as a compulsory simulator under STCW may lead to other issues such as slow development of ERS and lack of interest in this training. This information was able to answer RQ1, as well as provide preliminary knowledge for the researcher to investigate deeper into the actual reality in various areas such as maritime administrations, METIs and simulator manufacturers in terms of enforcement and implementation.

Although the MAs are responsible for monitoring and controlling the quality of the ERS related activities, the effectiveness of the learning process does not solely rely on the governance, but the classroom activities have higher influence in the learning process. The next section will explore the influence of dominant learning theories in ERS applications.

CHAPTER II

2.2 The learning theories and simulator activities

2.2.1 Educational Psychology approach

2.2.2 Behaviourism learning theory

2.2.3 Cognitivism learning theory

2.2.4 Constructivism learning theory

2.2.5 Connectivism learning theory

In these sections, the application of adult learning theories in ERS will be discussed, including other dominant learning theories applicable to ERS. The main intention is to explore these theories, which will be one of the critical factors of effective teaching.

Section 2.2.1 defines educational psychology and the compatibility of adult learning theories to ERS users. It also explains how motivation can become driving factors for adults to learn.

Section 2.2.2 presents the behaviourism learning theory, which explains how learning takes place when there is a change in behaviour as it is also triggered by surrounding stimuli.

Section 2.2.3 explains the cognitivist learning theory, which the learning process occurs when there is a change in the thinking process. This section also explains that learning is a mental process that can be split into a series of helpful steps.

Section 2.2.4 explains constructivist learning theory, where the knowledge is built by the students themselves, based on their previous knowledge.

Lastly, section 2.2.5 tells that learning is not inherently an internal process but may take place outside of the human brain as well via connectivism theory.

2.2.1 Educational Psychology approach

"Educational psychology is the study of how individuals learn, including topics such as student outcomes, the academic process, individual differences in learning, gifted learners and various learning disabilities" (Online Psychology Degrees, n.d.). This study will discuss the suitable learning theories for the application of ERS in MET.

Motivation commonly drives successful learning. Motivation is defined as a desire to do something. It may come from within individuals, which is called intrinsic motivation. The motivation that is driven by the external factors is termed extrinsic motivation (Slavin, 2013). In education, the institutions play a vital role in promoting intrinsic and extrinsic motivations for the learners to ensure that effective and successful learning is taking place.

The primary users of ERS are adult learners, and the concept of andragogy suits this type of learner best. The advantage of adult learners is that the majority of them are intrinsically motivated to learn, especially in the ERS learning content because of its relevance to their job scope (Knowles, Holton III, & Swanson, 2012) (Figure 8). In order to maintain momentum and keep learners motivated, the training should have a high level of realism. It will be easy for them to internalise the lessons and apply them in day to day activities while working.

Figure 8

Advantage of adult learners

Note. From *Principles of andragogy* by J. Rebecca & Hogue (https://www.youtube.com/watch?v=UgNeWsbKDUY). Copyright 2019 by Rebecca.

The essential philosophy in engaging adult learners is that training should be a student-centred learning environment (Egizii, 2015).

2.2.2 Behaviourism learning theory

In this theory, learning takes place when there is a change in behaviour, and learning is influenced by external factors and the environment. There are two types of external factors, namely operant conditioning and classical conditioning. Classical conditioning was discovered by Pavlov through an experiment with a dog, who salivated every time the food was introduced. In the experiment, a bell was rung every feeding time. As a result, the dog salivated every time it heard the bell ringing, regardless of whether the food was introduced or not. The bell is termed as a conditioned stimulus; salivation of the dog is called the unconditioned response, and the food is the unconditioned stimulus. The theory says that humans learn when they can possess different behaviour through conditioned stimulus.

The operant conditioning concept was developed by Skinner (1968), which explains that the external factors in the form of reinforcement through reward and punishment may lead to changes in voluntary behaviour (Bates, 2015). Examples of the positive reinforcement are a compliment, token system, credit system, grades and award. Besides, the immediate response is also considered as positive reinforcement. On the one hand, the reinforcement acts as the catalyst for the students to learn. On the other hand, punishment is the thing to avoid, which acts as a stimulus for the students to learn. It can be either they study because they want rewards or to avoid negative consequences. Both types of consequences are the factors for the students to change their behaviour.

This concept is widely used in the education system all over the world. The grading system is very commonly used, and failing students will not be able to graduate. All these external factors leverage extrinsic motivation as a reward for the learners.

The teaching machine concept that was introduced by Skinner in 1954 (Bonaiuti, 2011) is closely related to the concept of learning by using Computer-Based Training (CBT) of an ERS. The teaching machine consists of a set of questions, whereby the students have to write down the correct answer and they are able to check immediately whether the response is correct or wrong.

The behaviourism theory is the teacher-centred approach. Although it may seem like the students are learning through the ERS application, the developer of the programme is the one that teaches, not the ERS. The programme developer and the trainers who set the exercises have the same position as the textbook writer except the ERS is a more effective medium to externalise all the knowledge of the knowers. The teachers have to be active to prepare and develop the exercises.

A behaviourist teacher is almost the same as an objectivist teacher because they are much in control over what they want the students to achieve. The students have to follow the ERS programme. In this context, the most apparent distinction of this teacher-centred approach with another teacher-centred approach, such as a lecture is that the students also need to be active in interacting with the ERS application, and they can perform the tasks at their own pace. It will benefit both quick and slow learners. Unlike a lecture, in the ERS approach, the quick learners may finish the task faster, and they do not have to wait for the others to progress more. Since the MET syllabuses should comply with the STCW, behaviourism is perceived as a suitable approach for this.

2.2.3 Cognitivism learning theory

In curriculum design and development (CDD), the complexity of the contents is commonly categorised based on cognitive domains which are derived from Bloom's Taxonomy (BT). The content to be delivered is known as intended learning outcomes (ILOs) which are derived from the KUP tables in the STCW Code. There are six domains in BT, which are remembering, understanding, applying, analysing, evaluating and creating. The first two occur at the surface level, whereby the rest is categorised as in-depth understanding (Figure 9).

Figure 9

Bloom's taxonomies cognitive domains

Note. From *Taxonomies of learning by Harvard University* (https://bokcenter.harvard.edu/taxonomies-learning). Copyright by Harvard University.

In this hierarchy of learning, it is vital for the learners to progress step by step from the lowest level of remembering up to the creating level. The surface level is the building block for cognition at the in-depth level. The learners should be able to link the acquired knowledge from the surface level, to create better comprehension at the in-depth level. In this cognitivism theory, it explains that the learning takes place internally, through the mental process. Unlike the behaviourism theory, learning may take place without any sign of change in behaviour.

The ERS application under the STCW can be utilised at all levels of cognitive domains. As the ERS systems are complex, learning can be broken down into a series of manageable steps. For instance, the knowledge level is for the familiarisation with the ERS layout. The learners have to explore the system, identify all the types of machinery, systems and equipment of the simulator models.

In the next cognitive domain of understanding, the learners have to comprehend the function of each element. The understanding process is essential as learners tend to forget all the information that they received if they do not understand it. Once the learners have understood the function, they can move to the next level of application, and so on. Under the STCW, generally, the highest cognitive domain for support level is understanding; for operational level it is applying and for the management level it is evaluation (Table 2) (International Maritime Organization, 2017).

Table 2

The ERS Application Based on Bloom's Taxonomy

Level	STCW Code	Competence	Highest Cognitive Domain
Operational: Watchkeeping Engineer	Table A-III/1.1	Maintain a safe engineering watch	Applying
	Table A-III/1.3	Use internal communication systems	Applying
	Table A-III/1.4	Operate main and auxiliary machinery and associated control systems	Applying
	Table A-III/1.5	Operate fuel, lubrication, ballast and other pumping systems and associated control systems	Applying
	Table A-III/1.6	Operate electrical, electronic and control systems	Applying
	Table A-III/1.11	Maintain seaworthiness of the ship	Applying
Management level: Chief Engineer and Second Engineer	Table A-III/2.1	Manage the operation of propulsion plant machinery	Analysing
	Table A-III/2.2	Plan and schedule operations	Analysing
	Table A-III/2.3	Operation, surveillance, performance assessment and maintaining safety of propulsion plant and auxiliary machinery	Analysing
	Table A-III/2.4	Manage fuel, lubrication and ballast operations	Analysing
	Table A-III/2.5	Manage operation of electrical and electronic control equipment	Analysing
	Table A-III/2.8	Detect and identify the cause of machinery malfunctions and correct faults	Evaluating
	Table A-III/2.10	Control trim, stability and stress	Analysing
	Table A-II/2.11	Monitor and control compliance with legislative requirements and measures to ensure safety of life at sea and protection of the marine environment	Analysing
	Table A-III/2.14	Use leadership and managerial skills	Analysing
Support level	Table A-III/4.2	For keeping a boiler watch: Maintain the correct water levels and steam pressures	Understanding
Operational: Electro-technical Officer	Table A-III/6.1	Monitor the operation of electrical, electronic and control systems	Applying
	Table A-III/6.2	Monitor the operation of automatic control systems of propulsion and auxiliary machinery	Applying
	Table A-III/6.3	Operate generators and distribution systems	Applying
	Table A-III/6.4	Operate and maintain power systems in excess of 1,000 Volts	Applying
	Table A-III/6.5	Operate computers and computer networks on ships	Applying
	Table A-III/6.6	Use internal communication systems	Applying

Note. Adapted from *Model course 2.07: Engine-room simulator* (2017th ed.) by International Maritime Organization, 2017, IMO Publication. Copyright 2017 by IMO Publication.

2.2.4 Constructivism learning theory

Both behaviourist and cognitivist learning theories have systematic approaches, and are generally more teacher-centred, as the teacher is the one who sets what is to be learned. However, in constructivist learning theories, the approach is a bit different as it is more focused on student-centred learning. In this theory, it says that knowledge cannot be transmitted. However, the students are the ones who need to construct their own knowledge, based on prior knowledge that they had (Piaget & Elkind, 1967). The pre-existing knowledge may come from their own experience or through observation. In this context, the teacher is less active and only functions as a facilitator, to facilitate the learning process whenever it is necessary. It also relies on external factors and socialisation with other learners to enhance the learning process. This is also called situated learning, as learners develop knowledge independently or socially. Some scholars make a clear distinction between cognitive constructivism and social constructivism (GSI Teaching & Resource Center, 2016)(Table 3).

Table 3

Distinction between Two Constructivist Learning Theories

	Cognitive Constructivism	Social Constructivism
View of knowledge	Knowledge systems of cognitive structures are actively constructed by learners based on pre-existing cognitive structures.	Knowledge is constructed within social contexts through interactions with a knowledge community.
View of learning	Active assimilation and accommodation of new information to existing cognitive structures. Discovery by learners.	Integration of students into a knowledge community. Collaborative assimilation and accommodation of new information.
View of motivation	Intrinsic; learners set their own goals and motivate themselves to learn.	Intrinsic and extrinsic. Learning goals and motives are determined both by learners and extrinsic rewards provided by the knowledge community.
Implications for Teaching	The teacher facilitates learning by providing an environment that promotes discovery and assimilation/accommodation.	Collaborative learning is facilitated and guided by the teacher. Group work.

Note. From *Learning: Theory and research* by GSI Teaching & Resource Center (http://gsi.berkeley.edu/media/Learning.pdf). Copyright 2016 by UC Regents.

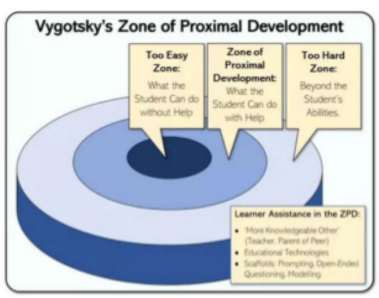
The constructivism theory is aligned with the adult learning theory. Perhaps, it will be more beneficial for cadets, who have sea-service experience, or the active seafarers, who are attending ERS training for self-development or upgrading their Certificate of Competency (COC).

The constructivism method takes a longer time compared to behaviourism and cognitivism as the learners have to perform self-regulated learning (SRL), and create their own knowledge. The two previous methods are more objectivist and rule-based and the teachers have full control over the contents to be delivered. However, scholars claim that constructivism is the best method to unlock the potential of learners, stimulate them to think critically and is a dynamic process of learning (Padirayon, Pagudpud, & Cruz, 2019).

The trainers play vital roles to guide and facilitate the learning process, to ensure the ILOs are met. The common concept that been used in social constructivism theory is the Vygotsky's zone of proximal development (ZPD), whereby it is essential for the trainer to know when is the right time to withdraw the supports to the learners, to ensure the learning process is maximised outside of their comfort zones. The learning process is the best when it is incremental. The trainer also has to ensure the learners are not losing their motivation and finding that the training is too hard due to the lack of support (Figure 10) (Fani & Ghaemi, 2011). Although it is more time consuming, this method is perceived as the best to develop critical thinking skills, which is more suitable for experienced students at operational and management levels. The learning environment will be more exciting and beneficial if all learners are coming from various kinds of background, but have the same common goals in learning. This group of people is called as community of practice, and is defined as a group of people in a specific environment who have casual relationships and exchange their expertise and perspectives because they have a shared interest (Sena & Shani, 1999).

Figure 10

Zone of Proximal Development



Note. From *Sociocultural theory of learning in the classroom* by C. Drew (https://helpfulprofessor.com/sociocultural-theory-education/). Copyright 2020 by Helpful Professor.

2.2.5 Connectivism learning theory

The most recent controversial learning theory is connectivism, which was developed by Stephen Downes and George Siemens for a digital age. It explains that learning is not necessarily an internal process. It can also happen outside of the human brain. This concept emphasises that knowledge is abundant externally, such as on the internet, within an organisation, and other means of a database. Learning becomes the ability to select appropriate information from external sources (Siemens, 2005). The typical analogy for connectivism by Siemens is *“the pipe is more important than what travels through it”*. It is not essential to understand the issue thoroughly as the information is abundant, and it is impossible to know and experience everything (Corbett & Spinello, 2020). Connectivism theory is more applicable in promoting lifelong learning as the ultimate goal is to produce autonomous learners. The involvement of the teacher only occurs at the initial stage of the learning environment as a guide and facilitator.

The principle of the STCW is to provide standards of competence. There are rigid syllabi that the training providers have to deliver to ensure compliance with the convention. However, the connectivism theory goes beyond standards. It promotes too many flexibilities, which makes knowledge acquisitions difficult and entirely subjective to measure. Nevertheless, the approaches are good at producing a high quality of seafarers.

Most scholars embrace the connectivism learning theory for developing online learning platforms (Bates, 2015).

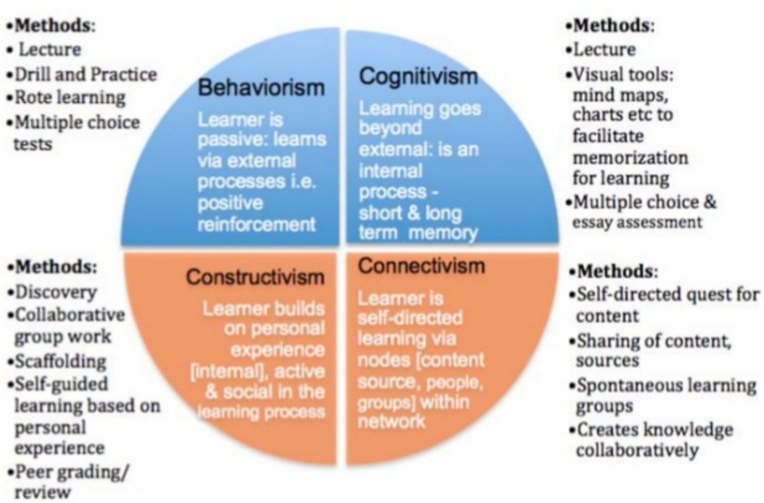
SECTION SUMMARY

Overall, the above sections distinguish the concepts of a few learning theories. The aim was to investigate the prevailing theories of learning, which would be one of the core factors for successful teaching.

Motivation is the driving force behind adult learners, and in order to suit their needs, the learning tasks should be objectivistic. Behaviourism learning theory emphasises on the importance of operant conditioning such as reinforcements and punishments as the main factor to change one's behaviour as an indication of learning. Meanwhile, cognitivism has expanded our understanding of how humans perceive and make sense of new information. Both behaviourism and cognitivism are teacher-centred learning styles. The other two learning theories use a student-centred approach. The first one is constructivism, where the knowledge is inherently contextual in nature, constructed from our experiences and norms that are mutually accepted. The second one is connectivism, which explains that learning is a process of linking dedicated nodes or sources of information. The applications of all learning theories are summarised below (Figure 11).

Figure 11

Dominant learning theories comparison



Note. From *How course design puts the focus on learning not teaching* by Debbie (https://onlinelearninginsights.wordpress.com/2013/05/15/). Copyright 2013 by Online Learning Insights.

There is no single learning theory that fits all situations, and most probably, the applications of learning theories in ERS are not mutually exclusive. Often, they are overlapped in teaching and learning activities (TLAs). By knowing the strengths and weaknesses of each dominant theory, it helps the relevant parties to appreciate the ways students learn and how to optimise them during the learning sessions.

It is obvious that understanding of how people learn is important to ensure effectiveness of classroom activities. However, effective governance is also vital in avoiding non-compliance, which could compromise the learning quality outcome. This information helped in answering the RQ1, as well as providing the underpinning knowledge for the researcher to explore the reality of the governance, applications of learning theories and other factors that may influence the effectiveness of ERS as a learning tool.

CHAPTER III

3 Qualitative Research Approach

3.1 Flexible design/qualitative approach

3.2 Method of data analysis and presentation

This chapter explains the research approach for this study and justifies why this method was chosen for this research.

Section 3.1 presents an overview of the qualitative research approach. It also explains the type of interview question that was used for the research and all the parties involved in the data collection process.

Lastly, section 3.2 tells the readers how the extractions of information from the interviews were made, and it explains the process of overcoming deficiency or inherent prejudices and issues resulting from single-observer research.

3.1 Flexible design/qualitative approach

The literature review from the previous chapter assisted the researcher in identifying the preliminary contents that are relevant to this study. The second research approach was conducted using a flexible qualitative approach. As the aim of this research is to explore MET practices concerning ERS, the best suitable method to meet the goal is the qualitative method (Table 4) *(Christensen, Johnson, & Turner, 2020).*

Table 4

Comparison of Research Methods

Characteristics of Quantitative, Qualitative, and Mixed Research Approaches*

	Quantitative Research	Qualitative Research	Mixed Research
Scientific Emphasis	Confirmation and falsification. Focuses on *testing* hypotheses and theories.	Exploratory. Focuses on *generating* hypotheses and theories.	Equal emphasis. Combines hypothesis/theory generation and testing.
View of the World	Mental processes and behavior are regular and predictable.	Mental processes and behavior are situational, dynamic, social, contextual, and personal.	Thought and behavior contain predictable and particularistic/contextual elements.
Primary View of Reality	Objective (material, physical, causal).	Subjective.	Combination of objective, subjective, and intersubjective.
Research Objectives	Explain (cause and effect), control, predict, description of characteristics of populations.	Explore, particular description, depth of understanding, social "construction" of reality.	Combination of objectives.
Research Purpose	Find general and complex laws of thought and behavior.	Describe and understand particular groups and individuals in particular contexts.	Integrate the general and the particular.
Data	Quantitatively measured variables (numbers).	Words, text, images, documents.	All data types are relevant; quantitative and qualitative data are both used in a single study.
Results	Generalizable findings.	Particularistic findings and claims.	Attempts to integrate general and particular, and produce "practical theory."
Final Report	Statistical results (with significance testing of correlations, differences between means) with discussion of results.	Narrative with rich contextual description and many direct quotations.	Mixture of statistics and qualitative data reporting.

Note: Reproduced from *Research methods, design, and analysis* (13th ed.) by L. Christensen, R. Johnson, & L. Turner, 2020, Pearson. Copyright 2020 by Pearson.

The multiple case study was employed in conducting this research, as this method helps the researcher to understand how and why contemporary events happen, issues and circumstances in ways not having control of these incidents or issues (Yin, 2014). Interviews were chosen as the method of data collection for providing clarity and enabling respondents to provide more in-depth answers to open-ended questions (Brace, 2013). This was because the respondents had in-depth information and participation in the maritime sector, as well as in ERS under the MET. The interview method is a better choice for answering the research questions. However, it heavily relies on the respondents' information, whether they are unbiased or not (Ghauri & Grønhaug, 2005). Therefore, semi-structured interviews were chosen over others as they allowed information comparison and comparing among the respondents and provided flexibility to obtain other relevant information (Dawson, 2006).

Stakeholders from various fields were identified as respondents for the in-depth and semi-structured interviews;

a) **Maritime administrations**
Key persons from the maritime administrations of Azerbaijan and Malaysia were interviewed to get insights from the authority side, in governing, monitoring and ensuring compliance of the ERS.

b) **MET experts**
There were two METIs involved in the data collection. The first one was the Malaysian Maritime Academy, known as Akademi Laut Malaysia (ALAM). ALAM is the pioneer and established METI in Malaysia, which has offered the ERS (Class A and B) training since 2006. Apart from that, ALAM has also established marine high voltage training by using high voltage simulators (Class S) since 2017. Open interviews were conducted with some of the key persons within that METI.
The second institution was Japan agency of Maritime Education and Training for Seafarers (JMETS). JMETS owns five training ships with ERS (Class B) installed onboard. Training ship is a compulsory programme for the final year cadets, prior to graduation. An open interview was done with an MET expert who works onboard those training ships, to get the insights on the utilisation of ERS onboard a ship.

c) **Simulator manufacturers**
The researcher had the chance to attend the webinars which were presented by the simulator manufacturer, Wärtsilä-Transas Simulator (Singapore branch) on 13th and 27th May 2020. The sessions were conducted to address the issue of COVID19, by introducing the new products of web-based simulators which are known as Wärtsilä Smart Simulation. The researcher had a chance to ask specific questions during the session and follow up with some relevant questions through email.
On 24th and 25th June 2020, the researcher had attended a webinar of Contemporary Maritime Issues. The guest speakers were from the world-leading maritime simulator provider, Kongsberg, Norway. Many issues, future planning and developments were discussed, including the company's mitigation of COVID-19 pandemic issues. In addition, the world-leaders in maritime satellite telecommunication and e-learning, Inmarsat and Videotel, respectively, were also part of the seminar. Although they are not directly involved in ERS training, they had provided insights from different angles, which are related to the utilisation of ERS.

d) **Seafarers**

Open-ended interviews with seafarers were carried out through Zoom application. Five senior engineers at management level, working with shipping companies from various countries, with numerous experiences with ERS were selected for this interview.

The data collections was mostly done through webinars, and some of the interviews were face-to-face. All of the interviews were recorded using Zoom, Microsoft Teams and Google Meet desktop applications and Voice Memos mobile application. Due to time constraints during the interview sessions, the researcher had to follow up a few matters through email and Whatsapp mobile application.

3.2 Method of data analysis and presentation

All the data from the interviews such as voice recordings, emails and texts from Whatapps mobile app were organised in a formal order into files and folders. The next step was reading and listening repeatedly and notetaking at the same time. The most relevant codes were determined and categories were established by putting together several codes. The codes were categorised into groups, and the interconnections were examined. The results were later summarised in a narrative form. Both deductive and inductive coding methods were employed in this process. However, the weight was more on the inductive method as the researcher performed an exploratory study, and had to build on data from scratch (Christians & Carey, 1989).

This method of using multiple case studies is called triangulation and is commonly used in research in the social sciences. It is also recommended to use this method as it enhances the validity (Campbell & Fiske, 1959) as well as making sense of the data and categorising it into appropriate groups (Creswell, 2013).

CHAPTER IV

4 Findings

4.2 General overview

4.3 Governance

4.4 IMO Model Courses

4.5 Learning tool

4.6 Constraints and limitations

4.7 Future developments

This section aims at providing research insights into the reality of teaching and learning through the use of ERS, by examining multiple areas as mentioned in the previous chapter.

Interviews were not conducted according to the plans entirely. Some conversations took an unexpected turn and opened a new field for study by the researcher. As a result, the same interview questions addressed different aspects of the issue. The key findings during the interviews are summarised into several categories.

Section 4.1 introduces the general perceptions of various stakeholders with regard to ERS. This is an opening remark before the researcher dig more details.

Section 4.2 explains the reality of ERS governance through various countries. Insights are not limited to maritime administrations but address other fields such as METIs and seafarers.

Section 4.3 presents the influences of IMCs on the usage of ERS.

Section 4.4 explores the current utilisations and perceptions of various parties regarding the ERS as a learning tool.

Section 4.5 indicates insights of various parties regarding the ERS as an assessment tool

Section 4.6 reveals the constraints and limitations of ERS

Lastly, section 4.7 presents the insights mostly from manufacturers concerning the future of ERS.

4.1 General overview

As the interviewees are mostly involved directly with ERS, the researcher found it easy to start the interview, without spending so much time on introducing the issues. Most of the interviewees agreed with the establishment of ERS in MET. One remarked,

> *"ERS is not a new thing. It has been developed since ages, and lots of improvement can be seen up until now. Although nothing can beat the real ship, this is the best that we have so far."*

Furthermore, the majority of the seafarers agreed that the ERS is the most practical tool to train beginners such as cadets due to limitations onboard a ship. High risks and hectic schedules were the most prominent findings that were highlighted by the majority of seafarers.

> *"…., it is impossible to train everything onboard a ship. For instance, the main engine crash stop, fire inside engine-room, and engine-room flooding. It can be done, but it will compromise the ship's operations, schedules and so on."*

The layouts of FM ERS gives the sensation of the real situation inside the ECR and will give more benefit, especially for those who are going to sail onboard highly automated vessels.

However, the simulator manufacturers admitted that there was still a lot of room for improvements concerning ERS. The concernied parties should grab this opportunity to fully utilise ERS as a learning tool. One of the remarks from a simulator manufacturer was as follows;

> *"ERS is just a tool, we don't have all answers for your questions, but we can provide you with a good platform for you to learn. It's up to the creativity of the course developers to design their training modules."*

A different view from training ships that have ERS onboard,

> *"It's good for specialised training, but we have real pieces of machinery here. It becomes redundant in some cases."*

4.2 Governance

From the interviews with various MAs, the current practices for ensuring the quality of the ERS can be summarised as,

> *"Any ERS training which is designed for the STCW certification purposes should get prior approval from the MA, by submitting the course specification, before the course can be conducted. The course developers have to prepare the*

> *course specification, outline all the specific information regarding the course in an agreed format, for the document assessment by the MA. The MA will assess the course specification based on the STCW to ensure that all elements of the required competence are covered. Often, the course specification is developed based on IMC, which can be considered as a comprehensive guideline. Once it meets the standards, the next step would be premise-audits by the authority to verify a few areas concerning the course. For instance, the capability of the trainers, the infrastructures, teaching and learning aids."*

From the interviews, the researcher also explored on the critical factors that concerned MAs. Most MAs agreed;

> *"There are two elements in that we are really concerned. The top priority is the capability of the trainers and followed by ERS features. That's why we really strict in issuing teaching permits for the trainers. We thoroughly check the suitability of the trainer accordingly."*

Due to the above issue, most of MAs obligate all the relevant parties in the METIs to undergo training based on IMC 6.09. If the trainer is also an assessor, IMC 3.12 training is mandatory. Additionally, for the ERS trainer and assessor, the IMC 6.10 training is a must, and the MA may request the trainers to undergo specific training conducted by the simulator manufacturer. Alternatively, the trainer may show proof that he or she has had on-the-job-training with other trainers and has gained practical operational experience on the specific type of simulator that is used. Although it is not mentioned in the STCW and IMCs that the ERS trainer and assessor should have the sea-service experience, most MAs make it as a mandatory requirement.

The MA also explained that as much as they wanted to monitor everything, their capacities are quite limited, and the METIs should be accountable for all operations:

> *"Every teaching aid has its own strengths and limitations. The METI should be able to address the limitation to meet the learning objectives. As ERS can be considered as complex equipment, the trainers and the support staffs should have acquired enough training and experience to operate it. If the training and assessment are well-planned and organised, and the learning activities are conducted accordingly, it will be really effective. We don't have the capacity to check all the operations. That's why documentation and record-keeping are important for us. The feedback from trainees also gives some weight to indicate*

the effectiveness of the process. We will check all these during the periodical audits. Once in a while, we will do unannounced-inspection."

From the METIs viewpoints, the practices by their MAs were fair, relevant and justifiable. One of the MET trainer mentioned,

"We just follow the IMO Model Courses and adjust accordingly. By doing this, we can make sure that we have a standard training because I believe all other countries also do the same."

4.3 IMO Model Courses (IMC)

From the interviews, IMCs were found to have a strong influence on various parties. The MAs used them as guidelines in approving the courses and METIs used them as guidelines in designing training modules. One of the key people from MA mentioned;

"Generally, the usage of all simulators, including ERS, are regulated by the STCW. More detailed technical aspects are covered by the class [classification societies = recognised organisations]. All operations are guided by the IMO Model Courses. The structured approach to uphold the quality of equipment, training and assessment is already good enough. It eases the monitoring and controlling process for the administration."

However, not all interviewees agreed on full reliance on IMCs. Feedback from the interviews indicated that there were some countries that didn't use the IMCs at all;

"Every country has a different education system. We never follow the IMO Model Course in designing our training and assessment."

The above statement was supported by another interviewee, from a different field, in a different context,

"IMO Model Courses are just guidelines, and they don't cover everything. For instance, we use ERS for our ERM [Engine-room Resource Management] course. We found the guidelines in the IMO Model Course 2.07 not really useful. We came up with our own exercises. It takes time until we reach what we have right now."

4.4 Learning tool

From the interviews, the researcher found out that ERS was not only for the ER department. It can be used for deck and shore personnel as well. As it covers the whole ER system with the 3D visualisation, it gives the idea for the participants about the ER operations.

However, the majority of the interviewees agreed that the utilisations of ERS was only suitable for the beginner level due to many factors. One of the factors was the features of ERS itself:

> *"In my view, the ERS training is only suitable for cadets, to give them some exposure and a better understanding of the real situation in the ER. Once they become professional, I don't find it necessary as we are learning while working. Furthermore, ERS seems beneficial for sophisticated vessel only. Unless if all ships are highly automated, then ERS is good for all."*

The majority of seafarers had high expectations of ERS. Most of them mentioned that this kind of technical training would only be beneficial if the METI provides specific training for a specific vessel, except at the cadet level. According to the expert on training ships, the ERS training system is very similar to the actual system on training ships, thus, making it an excellent training system.

Apart from that, seafarers also mentioned that it would be beneficial for the management or leadership courses to use ERS, rather than group discussion, case study or table-talk. Nevertheless, the ERS should be up-to-date to equip the new generations with the latest technological advancement knowledge.

One of the seafarer highlighted the issue of dealing with the low-end simulator,

> *"ERS should portray what we have onboard a ship. Some ERSs are outdated, and the cadets may have wrong perceptions and understanding about the system. If they ask to clarify, it's a good thing. But, most of the time cadets are inexperienced, and they don't even know what to ask."*

On the contrary, feedback from the METIs side stated otherwise. As much as the seafarers wanted the ERS to meet their expectations, the METIs had different viewpoints;

> *"Effectiveness of ERS utilisation strongly relies on the capability of the trainer. It is not limited to only during the exercises; it starts from the beginning of designing the training itself. Thanks to the IMO Model Course for helping us in that process. Additionally, the suitability of ERS type with learning objective should be considered. For instance, CBT [Class B] is for familiarisation,*

procedural and analysis exercises and Full-Mission [Class A] is for teamwork, communication and watchkeeping training."

Another MET expert also added crucial other roles of ERS trainers:

> *"A good ERS trainer should be able to navigate the classroom, to ease the learning process and provide good familiarisation. The trainer should be able to set the mental model of the trainees, to treat the ERS as a real situation on board a ship."*

The above statement was supported by another seafarer from a different approach, which focused on skills development:

> *"It doesn't matter what kind of ERS we have. The most important thing is to meet the learning objective. It doesn't have to be really complex, as long as it can develop the technical-skills, critical-thinking and common sense for engineers at the operational level."*

Another remarkable key finding during the interview with an METI expert identified the debriefing as the most important aspect in the ERS class:

> *"Debriefing is the most important session in the simulator learning session. The session should be engaging, interactive and able to clarify all doubts."*

The simulator manufacturer did highlight an issue, which was whether the ERS is user-friendly enough or not. However, they believed that no simulator is perfect, and it all depends on the practicality, as well as the time spent on using it to increase the familiarity with the system.

4.5 Constraints and limitations

From the operation side, most of the issues are related to the financial aspect:

> *"As much as we are trying to make it very comprehensive, we also struggle with the financial constraints. Initially, we incorporated ERS training with cadetship programme. When the economy turned down, some funders were resistant by saying ERS training is not compulsory under the STCW. We had to redesign our training, shorten the duration, to make it optimum."*

Some other insights from seafarers agreed with the strong influence of the financial aspect:

> *"We already had too many courses to attend. Although ERS training is beneficial, if we have to pay by ourselves, we have to be selective, and most of the time, seafarers only attend the mandatory courses."*

The financial issue also had a domino effect which led to other issues such as a competent trainer. Based on the interviews, the majority agreed that the usage of ERS could only be effective if it is well-planned and structured for any activities. The best case scenario is that the person-in-charge of the ERS has years of experience dealing with the ERS. The issue was how to retain an experienced marine engineer to be the person in charge of the ERS. Some METIs hired the guest lecturers for this task, and assigned a technician to assist them. The technician may have limited knowledge about ship operation and most of the time, the technician and the trainer do not speak in the same frequency. According to MAs, the requirement of teaching permit should allow some flexibility to overcome the above issue.

Another key finding that has been highlighted by most of the interviewees was the reliability of the ERS:

> *"Some training centre could not afford the latest and high-end ERS. This issue seems debatable because the effectiveness of the training is not solely based on simulator features. As the trainers also hold the responsibility and have to play significant roles in order to suit the pedagogical elements in the simulation training, regardless of the presentation and features of the ERS. However, the ERS should be reliable with very minimum technical issues. If the system always gets hanged during the learning activities, it will interrupt the learning process, and the participants may lose motivation."*

4.6 Future developments

There are a number of developments in process, and some already available in the market. One is digital twin technology, a simulator setup which replicates exactly the situation onboard. A training needs assessment can be done through digital twinning by getting real-time data. The specialist may know the ways the seafarers operates the vessel and make suggestions for training accordingly.

The simulator manufacturers try their best to address all the common issues and limitations of the ERS. One of the simulator manufacturers mentioned:

> *"I would say that the biggest and greatest change in the immediate future will come from the introduction of VR headsets. Building 3D environment is becoming much easier than before thanks to the available tools, and I believe that creating the right immersive experience it will be key in sparking even higher interest from the students, which in return, of course, will increase the retention. This is to address the issue of realism as well."*

Most of the interviewees forecast that fuel and energy management training would be a future trend, since fuel consumption is the highest proportion of cost in shipping. The ERS capable of providing proper training, which may produce competent seafarers to operate the vessel efficiently. One of the simulator manufacturers also addressed the same thing:

> *"Demand for training depends on the market. Due to Sulphur Cap 2020, more demands related to environment impact features such as cleaner fuels and renewable energy. Furthermore, different customers will have a different request in regards to different latest technologies such as Ballast Water Treatment System (BWTS), Selective Catalytic Reduction (SCR), exhaust scrubber system and LNG-fuelled."*

Apart from that, another area of concern is the availability of reliable internet connectivity. Nowadays, the cloud-based ERS can be run without any hiccups. The only issue is the trainer and students have to adapt to this kind of contemporary training method. The COVID pandemic has expedited the development of this technology.

CHAPTER SUMMARY

Overall, this chapter attempted to provide empirical insight into the nature of teaching and learning with ERS by exploring several fields. The strengths and limitations of ERS were acknowledged by interviewees from multiple fields. All agreed that ERS is beneficial to illustrate the real situation in the ER, but it also has certain limitations which need to be addressed. However, ERS is the best that the MET has so far to train the ER personnel in a low-risk environment yet cost-efficient environment.

In terms of governance, the MAs strictly control the METIs activities to ensure compliance with STCW. Most of the MAs require specific criteria to ensure the ERS trainers are really qualified and competent to conduct the classes, as they perceived the trainers as the backbone for the effectiveness of the learning process. A majority of countries use IMCs as guidelines, for the MAs in approving courses, and for METIs in designing their training modules. However, due to some circumstances and different viewpoints, not all countries solely rely on IMCs.

The majority of the seafarers perceived the ERS as only being suitable for cadets. A different opinion from another seafarer said that ERS could be utilised for all levels, preferably technical-skills for the operational level, and management-skills for the management level. The majority agreed that ERS could be more beneficial for specialised training on a particular vessel, and it was proven according to the expert from the training ship that is using this kind of system.

As much as seafarers believed that complex ERS with a high level of realism is the topmost priority, the METIs and simulator manufacturers argued as they think that the main factor is the trainer itself. The trainer should be able to do proper planning and classroom management in order to fully bring forth the ERS potential. However, the limited resources made it difficult to address many of the issues in the ERS context.

Simulator manufacturers have come out with many of developments to address various issues of realism, specialised training, and COVID. Apart from that, the developments intend to cater to the demand from the industry.

The findings from this chapter helped to answer RQ2 and RQ3, which will be used to formulate answers for RQ4 in the next chapter.

CHAPTER V

5 Discussions and conclusions

5.1 Governance of ERS

5.2 Learning theories in real ERS situations

5.3 Incorporate the ERS in the TLAs

5.4 Comprehension of the lesson plan

In this chapter, the empirical study will be discussed to answer RQ4. Although the findings do not portray the ERS situations globally due to the limited number of respondents, small sampling area and time-constraints, the discussions are relevant for the related parties to consider in dealing with ERS.

From the interviews, it can be concluded that the effectiveness of ERS as a learning tool is strongly influenced by the trainers, in terms of classroom delivery, management as well as designing and planning for the training modules.

Section 5.1 discusses the approach by the MAs in ensuring the quality of MET through ERS.

Section 5.2 interprets the findings through the lenses of applicable dominant learning theories.

For planning purposes, section 5.3 discusses in detail the key considerations prior to incorporating the ERS in the TLAs.

Section 5.4 explains the importance of lesson plan and vital points in ERS lesson plan.

Lastly, all the discussions will be summarised, and conclusions will be made based on the consolidation of analysis.

5.1 Governance of ERS

From the findings and the literature review, it can be concluded that the MA plays a significant role in ensuring compliance with international conventions. Although the regulation of QSS under the STCW has provided clear guidelines for maintaining the standards, nothing limits the MA from performing far beyond the standards. However, the MA has to consider the capacity of the state in implementing their own enhanced-standards, in order not to burden all the related parties. The inputs from all stakeholders, such as METI players, shipping companies, and seafarers' unions, are essential in determining the local standards.

From the findings, generally, all the ERS should be approved by the ROs. Although it is not stated under the STCW, the majority of MAs make it a clear-cut rule to eliminate the issue of substandard ERS. However, another general problem in METIs is to get a qualified person to become a trainer and assessor for the ERS. Since the ERS is a sophisticated learning tool, a strong foundation, with years of experience and excellent pedagogical skills is important in ensuring the quality of the ERS-based education. There are no specific written requirements for the ERS trainer and assessor under the STCW and the IMC. This is where the function of MA is vital to ensure the METIs do not compromise quality by hiring unqualified ERS-trainers. Therefore, the obligation of pedagogical training such as IMC 6.09, 3.12 and 6.10 is a good approach by the MAs.

The MA also has to understand the concerns and should not mandate unrealistic requirements for the METIs to obey. For instance, financial constraints, inadequate teaching infrastructures, and lack of qualified teaching staffs are the main issues for the MET in China (Dong, 2014). Difficulties in getting a qualified ERS trainer is a serious worldwide issue. This is similar to the findings obtained. If the standards by the MA for ERS trainers are set too high, there will be difficulty in getting the positions fulfilled. For instance, a highly experienced seafarer will demand higher pay. Retired seafarers, on the other hand, may raise some issues; lack of updates on digital skills, less-energetic, and lack of passion for teaching. From the current study, this issue leads to the trend of hiring young ERS trainers with less seafaring experience by most METIs as approved by MAs. This issue is debatable, as some scholars argue that experience is not the ultimate factor but the pedagogy skills that count (Brcko, Perkovic, & Luin, 2016). Apart from that, a young trainer also has better potential to establish a teaching and academic career. Ideally, the trainer should have strong knowledge of the subject and provide insightful content with a strong theory and practice balance (Semjonovs, Bogdaņecs, & Fernández González, 2015).

5.2 Learning theories in real ERS situations

According to the study, it can be concluded that all the cadets that are being trained in METI are inexperienced. Since they are explicitly trained to become seafarers, it projects higher motivation compared to those who have an uncertain career path after they finish studies. However, when it comes to intrinsic motivation to learn, it will be more tangible for experienced seafarers, who are attending the training for refresher courses and continuous learning. This is aligned with adult learning theories, which was covered under previous chapters.

The researcher also discovered that the understanding of learning theories would benefit the learning activities.

- Behaviourism

The usage of the CBT (Class B) provides specific learning objectives, computer-assisted instruction, and immediate response by the simulator system. For instance, in procedural training of "Starting-up a boiler from the cold condition", the learners are provided with a checklist, and they have to follow the procedure in a right sequence to complete the task. As the students are going through the exercise, performing the tasks step by step, and giving ticks to all the completed points in the checklist, it reinforces the learner to proceed until the end. The students may know whether they have performed the tasks correctly or not because the system will give errors if there is procedural error along the way. For example, if a student has prepared the line for the boiler fuel system, when he presses the pump's start button, the pump starts to run, and there is an indication of a rise in the line pressure and temperature; the flow indication and the simulator system produces the sound of running machinery. This immediate response tells the student that he or she has performed it correctly; this is a good outcome. On the other hand, if the student has missed the correct step and is unable to start the pump, this is an adverse outcome. The students are extrinsically motivated because they want to get good outcomes and avoid adverse outcomes. Perhaps the extrinsic motivation will drive the intrinsic motivation through this approach, which means the students will find the tasks as enjoyable.

- Cognitivism

The results show that the IMCs have a strong influence on the METIs in designing the curricula. All the IMCs show the same pattern of design, including ERS related IMCs. For example, as shown in Table 5, the learning session starts with familiarisation, followed by learning about each subsystem and finally, the main engine system. The complexity of the topic is gradually increased, to ensure the students have a good comprehension before moving to the next topic. There will be some repetitions in different exercises, for cognition purposes, and repetition is the key to building expertise (Sellberg & Viktorelius, 2020).

Table 5

Outlines of an ERS training for Section A-III/1 of STCW Code

No	Topic	Hours
1	**Familiarization**	**6**
1.1	Plant arrangement	2
1.2	Instrumentation	2
1.3	Alarm System	1
1.4	Controls	1
2	**Operation of plant machinery**	**20**
2.1	Operational Procedures	1
2.2	Operate main and auxiliary machinery and system	3
2.3	Operation of diesel generator	2
2.4	Operation of steam boiler	2
2.5	Operation of main engine and associated auxiliaries	4
2.6	Operation of steam turbo generator	2
2.7	Operation of fresh water generator	1
2.8	Operation of pumping system	2
2.9	Operation of oily water separator	1
2.10	Fault detection and measure	2
3	**Maintain a safe engineering watch**	**19**
3.1	Thorough knowledge of principle to be observed in keeping an engineering watch	10
3.2	Safety and emergency procedures; change over of remote/automatic to local control of all sytem	2
3.3	Safety precautions to be observed during a watch and immediate actions to be taken in the event of fire or accident, with particular reference to oil system	2
3.4	Knowledge of engine room resource management principles	5
4	**Operate electrical, electronic and control systems**	**4**
4.1	Operation of main switchboard	2
4.2	High-voltage installations	2
	Total	**49**

Notes: Reproduced from *Model course 2.07. Engine-room simulator* by International Maritime Organization, 2017. IMO Publication. Copyright 2017 by IMO Publication.

- Constructivism

As mentioned in Chapter II, constructivism is found to be effective but time-consuming. Often in ERS class, the trainer lets the students explore the system by themselves to construct their own knowledge. Constructivism is also suitable for debriefing sessions whereby the trainer will facilitate the session, and the learners will self-assess themselves.

Nevertheless, the experience is not always an advantage for a learner as it can hinder the learning process from taking place. Based on the interviews, some seafarers have high expectations and want the ERS to be the same as a real ship. Diminishing the old habits in order to learn new things is challenging (Stone, 2014). In the ERS environment, an experienced participant may find it challenging to control and monitor the plant through colourful digital displays, especially if they have never experienced it before and are used to analogue and traditional displays. Besides, in a real situation, most of the engineers rely on their human senses while performing the duty of the engine-room (ER) round-check. All of the senses are used while performing a round-check duty:

- sight is used to performed visual inspection,
- hearing is essential to detect abnormal machinery sound,
- smell is useful for detecting fuel oil or chemical leaks and burning smell
- taste is used to identify the source of the leak whether it is seawater or freshwater,
- touch is used to feel the temperature, access the excessive vibration and feel the texture.

However, there are possibilities that there is a student in the ERS class who has experience in a highly automated ER, whereby all the ER parameters can be monitored from the Engine Control Room (ECR). The modern ER is equipped with real-time cameras which are located at various locations to ease the monitoring process of the ER (Monarch Telecom, 2019). Various kinds of sensors are everywhere and act as a replacement for human senses. From the ECR, the duty engineer may observe all essential parameters, without going to the ER. By doing this, it minimises the human intervention inside the ER, and all the operational tasks can be performed within the ECR only (Mitsubishi Heavy Industries, 2008). A person with experience sailing onboard highly automated vessels may have an advantage in attending ERS training, as it has the same philosophy as the ERS. A mixed background of participants may have advantages as they can socialise with each other. This is also where the social constructivism learning theory takes place. Furthermore, the transfer of tacit knowledge from one learner to another is possible through socialisation (Nonaka, 2008).

The trainer also needs to promote and facilitate the learning process, such as through engaging session, team exercise and discussion. Therefore, it is important for trainers to know the strengths and weaknesses of their participants beforehand.

- Connectivism

As discussed in Chapter II, connectivism learning theory is not objectivist and contradicts the STCW philosophy. However, based on the study, the learners could benefit from this concept of learning in ERS applications, especially for crisis and troubleshooting exercises. In these circumstances, a seafarer may not understand the problem completely, but the information and troubleshooting idea can be accessed from others through networking (Corbett & Spinello, 2020). However, the learner has to be selective in applying the necessary knowledge through networking, whenever it is necessary to solve an issue. Connectivism focuses on developing critical thinking skills by filtering and reasoning the redundant data in decision-making. According to Siemens (2004), decision-making is also considered to be a learning process.

5.3 Incorporate the ERS in the TLAs

In order to ensure that the learning process by using ERS is valid, other than learning theories, there are multiple factors to consider. The most crucial factor in ensuring the effectiveness of usage of the ERS in the TLA is the planning process. As mentioned in the previous chapter by one MET expert,

> "*.... It is not limited to only during the exercises; it starts from the beginning of designing the training itself....*"

Ideally, the consideration of incorporating ERS in the TLAs should begin in the curriculum design and development (CDD) phase itself. Based on the interviews, the main constraints of running the ERS training are financial, workforce and facilities. Therefore, planning is crucial to ensure that the resources are well-utilised in order to avoid unnecessary use.

The holistic CDD process needs to be understood by the course developer particularly, in considering the ERS as a learning tools. The definition of CDD is as follows:

- Curriculum design: Defining the essential elements of the curriculum and their interaction with each other.
- Curriculum development: A process consisting of a systematic and well-organized preparation of what needs to be taught and learned to create a detailed curriculum blueprint

(Yoga, 2018).

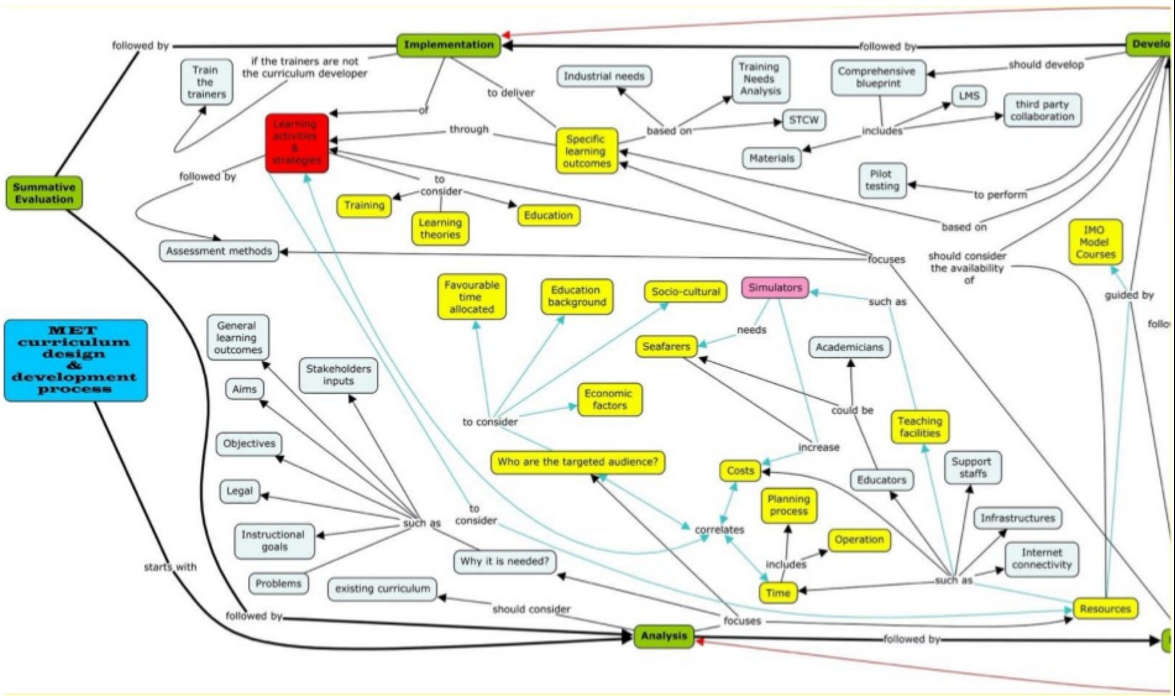
One of the most comprehensive but straightforward models or frameworks in the CDD process is the ADDIE model, which originated from the United States of America (USA). ADDIE stands for analysis, design, development, implementation and evaluation. This model is widely used by training and education developers such as the United Kingdoms (UK) Open University (Bates, 2015). The concept map (Figure 12) shows an overview of the CDD process by using the ADDIE model. As can be seen from the figure, the usages of ERS in the TLA are influenced by various elements, such as;

- The learning objectives
- The target audience
- Time available
- Costs
- Workforce
- Learning aids.

All these elements will be further discussed in the following sections. The appropriate TLA selection is the vital factor for the effectiveness of the learning process as it will provide a formal but versatile mechanism to ensure that students meet and surpass educational objectives (Khandve, 2016).

Figure 12

Concept map for MET curriculum design and development



Note. The figure shows the ADDIE model in curriculum design and development and process. The main elements of the ADDIE process are labelled in green. The yellow boxes are the significant elements that influence the selection of ERS as a learning tool, which takes part in the process labelled in red.

5.3.1 Intended learning outcomes (ILOs)

As discussed earlier, the most popular approach among learning institutions to categorise the difficulty level of ILO is by using BT. The verb used in the ILO represents the level of comprehension needed by the remembering and understanding domains for the surface level, and the rest for in-depth comprehension. Under the MET curricula, the ILOs are the products from the competence standards, which are stated under the STCW Code. The IMO also sets out the IMC as a detailed framework for METIs to design and develop their curricula. The majority of interviewees believed that the IMCs have a strong influence in designing the curricula as well as guidelines for MAs in course approval processes.

Apart from the STCW requirements, the training needs analysis (TNA), the professional judgement of the trainers, and inputs from stakeholders may also influence the development of additional ILOs. Some private METIs rely on funding from the students' sponsorships to operate, whereby, in this case, the sponsors have a significant influence in deciding the ILOs of the training programmes (A. Prylipko, personal communication, March 6, 2020).

The ILO is the first consideration in determining the usage of ERS as a training tool. Based on the interviews, the researcher has produced non-exhaustive guidelines for choosing the correct TLA, based on the level of difficulty of the ILO and examples of ERS applications (Table 6). As can be seen, the ERS applications can be matched at all levels of comprehension.

Table 6

Instructional Strategy Based on the Level of Difficulty and ERS Application.

Instructional Strategy	Cognitive Domain (Bloom, 1956)	Affective Domain (Krathwohl, Bloom, & Masia, 1973)	Psychomotor Domain (Simpson, 1972)	ERS Application
Lecture, reading, audio/visual, demonstration, or guided observations, question and answer period	1. Knowledge	1. Receiving phenomena	1. Perception 2. Set	Demonstration, familiarisation exercise
Discussions, multimedia CBT, Socratic didactic method, reflection. Activities such as surveys, role playing, case studies, fishbowls, etc.	2. Comprehension 3. Application	2. Responding to phenomena	3. Guided response 4. Mechanism	Procedural training, team training, maintenance training
On-the-Job-Training (OJT), practice by doing (some direction or coaching is required), simulated job settings (to include CBT simulations)	4. Analysis	3. Valuing	5. Complex response	Watchkeeping exercise, Troubleshooting exercise
Use in real situations. Also may be trained by using several high level activities coupled with OJT.	5. Synthesis	4. Organize values into priorities	6. Adaptation	Energy management, troubleshooting
Normally developed on own (informal learning) through self-study or learning through mistakes, but mentoring and coaching can speed the process.	6. Evaluation	5. Internalizing values	7. Origination	Research, developing energy management plan, scenario planning, creating contingency plans

Notes: Adapted from *Learning strategies or learning strategies* by The Performance Juxtaposition (http://www.nwlink.com/~donclark/hrd/strategy.html). Copyright 2010 by The Performance Juxtaposition.

5.3.2 Available resources

Another important factor to consider when selecting ERS as a learning tool are the resources available in the institution. Those components are not mutually exclusive and are strongly interrelated. The duration allocated for any learning activities is very critical in deciding the TLA, as some tasks may consume more time than others. A teamwork exercise, for example, involves familiarisation of equipment, briefing and debriefing for each exercise. The learning outcomes could not be met if the trainees are not familiar with the ERS system (Zincir, Dere, & Deniz, 2017). As guided by IMC 2.07, the familiarisation exercise for the whole system of ERS may take approximately six hours (Table 4).

The time taken for an ERS exercise during the debriefing session should also be taken into account. As mentioned by one of the METI experts during the interview, *“Debriefing is the most important session in the simulator learning session. The session should be engaging, interactive and able to clarify all doubts.”*

This statement is also supported by Sellberg (2018) who notes that the debriefing is the most critical part of the ERS and other simulator training as it will transform the experience into learning. The time taken during the debriefing session is a crucial factor in determining the effectiveness of the learning process.

Although the STCW does not mandate contact hours, most MAs use the IMCs as strict guidelines for establishing them. However, the decisions about contact hours are also influenced by other stakeholders such as seafarers' unions and government-linked shipping companies in ensuring the optimum duration for the benefits of the national economy (M.E. Manuel, personal communication, January 22, 2020). This is where the conflict between effectiveness and efficiency is involved in deciding the optimum point of study duration. Ideally, the short course duration should be less than 30 hours (7 hours per day x 5 working days), considering the active seafarers. They are attending the training during their holidays. An METI should consider avoiding unnecessary costs or working over the weekend. More consideration should be given to self-funded seafarers, as a more prolonged course would result in higher course fees and other costs such as travelling, accommodation, and meals. For instance, although in the IMC 2.07 (Table 5), the guideline for contact hours is 49 hours (more than seven days). Many training providers and countries make necessary adjustments to reduce the duration, such as India, which made it 21 hours (Director General of Shipping Govt. of India, 2019), and Maersk Training (Larsen, 2018).

Another resource that should be considered is what kind of ERS will be employed during the TLAs. During the planning phase, one should know the strengths and weakness of the ERS that the institution has and its suitability for the learning activities. This may affect the learning duration as well. For instance, some ERS features are too complicated, which requires more time for familiarisation. However, a good structure of tasks sheets and guidance from the ERS trainer may compensate for these issues. If the time permits, the trainer may let the student self-explore the ERS layout, to familiarise themselves with the system as this method gives excellent benefits in terms of experiential learning. Alternatively, if the duration allocation is too short, the trainer has to perform more demonstrations rather than letting the students learn by themselves. However, duration of ERS familiarisation depends on the learning objective, as well. For instance, based on the interviews, some training centres incorporate ERS for soft-skill and leadership training in engine-room resource management (ERM) courses. In this case, ERS is just a platform to learn and practice the soft-skills. As ERM is not a technical course, during the ERS familiarisation, the trainer may assist the students as much as possible to ensure it is progressive and the core focus is on non-technical skills. Otherwise, the students will face difficulties dealing with the new environment of ERS, and the training objectives of ERM cannot be met. Having said this, it does not mean that technical and non-technical training are mutually exclusive. Often in objectivist technical training (STCW), the non-technical element is part of the hidden curriculum, thus, the two elements should be inseparable (Sellberg & Viktorelius, 2020).

The DNV-GL has provided a comprehensive classification of ERS, according to suitability with the STCW competence standards (Table 7).

Table 7

Competencies Addressed by Machinery Operation Simulator Class

STCW reference	*Competence*	*Class A (ENG)*	*Class B (ENG)*	*Class C (ENG)*	*Class S (ENG)*
Table A-III/1.1	Maintain a safe engineering watch.	A	B		(S)
Table A-III/1.3	Use internal communication systems.	A	B		(S)
Table A-III/1.4	Operate main and auxiliary machinery and associated control systems.	A	B	C	(S)
Table A-III/1.5	Operate fuel, lubrication, ballast and other pumping systems and associated control systems.	A	B	C	(S)
Table A-III/1.6	Operate electrical, electronic and control systems.	A	B	C	(S)
Table A-III/1.11	Maintain seaworthiness of the ship.	A	B		(S)
Table A-III/2.1	Manage the operation of propulsion plant machinery.	A	B		(S)
Table A-III/2.2	Plan and schedule operations.	A	B		(S)
Table A-III/2.3	Operation, surveillance, performance assessment and maintaining safety of propulsion plant and auxiliary machinery.	A	B		(S)
Table A-III/2.4	Manage fuel, lubrication and ballast operations.	A	B	C	(S)
Table A-III/2.5	Manage operation of electrical and electronic control equipment.	A	B		(S)
Table A-III/2.6	Manage troubleshooting restoration of electrical and electronic control equipment to operating condition.				(S)
Table A-III/2.8	Detect and identify the cause of machinery malfunctions and correct faults.	A			(S)
Table A-III/2.10	Control trim, stability and stress.	A	B		(S)
Table A-III/2.11	Monitor and control compliance with legislative requirements and measures to ensure safety of life at sea and protection of the marine environment.	A	B		(S)
Table A-III/2.14	Use leadership and managerial skills.	A			
Table A-III/4.2	For keeping a boiler watch: Maintain the correct water levels and steam pressures.	A	B	C	(S)
Table A-III/6.1	Monitor the operation of electrical, electronic and control systems.	A	B		(S)
Table A-III/6.2	Monitor the operation of automatic control systems of propulsion and auxiliary machinery.	A	B		(S)
Table A-III/6.3	Operate generators and distribution systems.	A	B		(S)
Table A-III/6.4	Operate and maintain power systems in excess of 1,000 Volts.				(S)
Table A-III/6.5	Operate computers and computer networks on ships.	A	B		(S)
Table A-III/6.6	Use internal communication systems.	A	B		
Table A-III/6.8	Maintenance and repair of automation and control systems of main propulsion and auxiliary machinery.				(S)
Table A-III/6.9	Maintenance and repair of bridge navigation equipment and ship communication systems.				(S)
Table A-III/6.10	Maintenance and repair of electrical, electronic and control systems of deck machinery and cargo-handling equipment.				(S)
Table A-III/6.11	Maintenance and repair of control and safety systems of hotel equipment.				(S)
Table A-III/7.5	Contribute to the maintenance and repair of electrical systems and machinery on board.				(S)

Notes. From *DNVGL-ST-0033: Maritime simulator systems* by DNV GL (https://rules.dnvgl.com/docs/pdf/DNVGL/ST/2017-03/DNVGL-ST-0033.pdf).

Class A (ENG) or known as Full-Mission (FM) ERS is suitable for almost all types of training except for high voltage and electrical maintenance training. However, Table 7 is not the ultimate factor for the selection of ERS for an appropriate ILO. As mentioned in the findings,

> *"Effectiveness of ERS utilisation strongly relies on the capability of the trainer."*

Therefore, the course developers should perform the test by themselves, and make necessary adjustments for all relevant aspects such as timing instructions during the briefing, number of tasks and exercise sheets. The process does not end there as it is subjected to continuous improvement.

As the ERS is proven as a practical learning tool, it comes with a high price as well. Not only is the equipment itself is expensive, other resources involved in the execution of the training also may influence the total cost. Cutting costs may result in less effective training. Two categories in determining the costs for using ERS are;

- The planning costs: This process includes the involvement of the stakeholders, consultant fees and time spent researching and developing the course contents (Videotel, 2018). From the empirical study, for the STCW related training, IMCs have a strong influence on CDD. However, usage of ERS as a learning tool is not only limited to the STCW courses but other developmental courses as well, such as crisis management and scenarios planning, which are not provided under the IMCs. Developing an excellent training module requires a proper and lengthy planning process. Once an METI has developed various sets of exercises and scenarios for the ERS learning activities in the new development of a course, it will be a lot easier as it only involves a mix-and-match process, rather than starting from scratch.
- The operation costs; Costs may include infrastructure expenses such as electricity, trainers' opportunity costs when performing training, external trainers' wages, and time spent by staff on training, both pre-and post-training. The minimum and maximum numbers of participants should be included, as well. There is a limit for the teacher to student ratio, as too many participants may compromise the effectiveness of the learning process. If the number of participants is too small, it will not be cost-effective, and some team exercises are not possible to conduct effectively.

This is more important for private METIs, as they rely on the funding of the course fees for the business continuity. As a result, the training rates should be practical and reasonable in order to attract clients. Ideally, the cost-benefit analysis should be carried out by the clients in order to assess the essence of the training. However, the outcomes of the study showed that self-funded seafarers often ignore it. Instead of long-term benefits, they are more concerned with renewing their COC. As much as the METIs want to provide the best training using ERS as a learning tool, the economic factor may become a barrier for them to do so. The simulator manufacturers may come up with new technologies and features to overcome the multiple issues in ERS, such as the Digital Twin, VR technology and cloud-based ERS. Fortunately, nowadays, the simulators are becoming more affordable because of the emerging technologies and increase in the number of suppliers (Mallam, Nazir, & Renganayagalu, 2019). However, the total costs for upgrading the ERS or purchasing a new set of ERS should be considered as well to determine whether it is worthwhile or just a splurge.

5.3.3 Students' pre-existing knowledge and experience

Some METIs integrate the ERS training in the COC programme, whereby by the end of the studies, apart from the COC, the students will also acquire a degree or diploma in Marine Engineering. The METI usually sets the academic entry standards for the students of the COC programme, which are based on ILOs and other requirements such as the national education policy and the STCW (Ziarati & Demirel, 2012). For example, the applicants are required to have a good grade in mathematics and science in a high school examination as an entry requirement for the COC programme of the WKE (SUNY Maritime College, 2020).

In fact, under the same programme, the training regime for the first-year student will be different from those who have gained seagoing experience. From the findings:

"We had to redesign our training, shorten the duration, to make it optimum."

There are some debates among MET experts as to whether the ERS training should be done before the cadets go for the shipboard training or after they come back from shipboard training. As discussed earlier, ERS training is suitable at all levels of comprehension. Nevertheless, the method of delivery determines the effectiveness of the learning process.

Ideally, the ERS training should be done prior to and after the shipboard training, to gain the maximum benefits (Cicek & Uchida,). However, due to financial and time constraints, some METIs sets a prerequisite requirement for a specific duration of shipboard experience, before joining the ERS training. By doing this, the duration of training can be shortened but effective.

5.4 Comprehension of the lesson plan

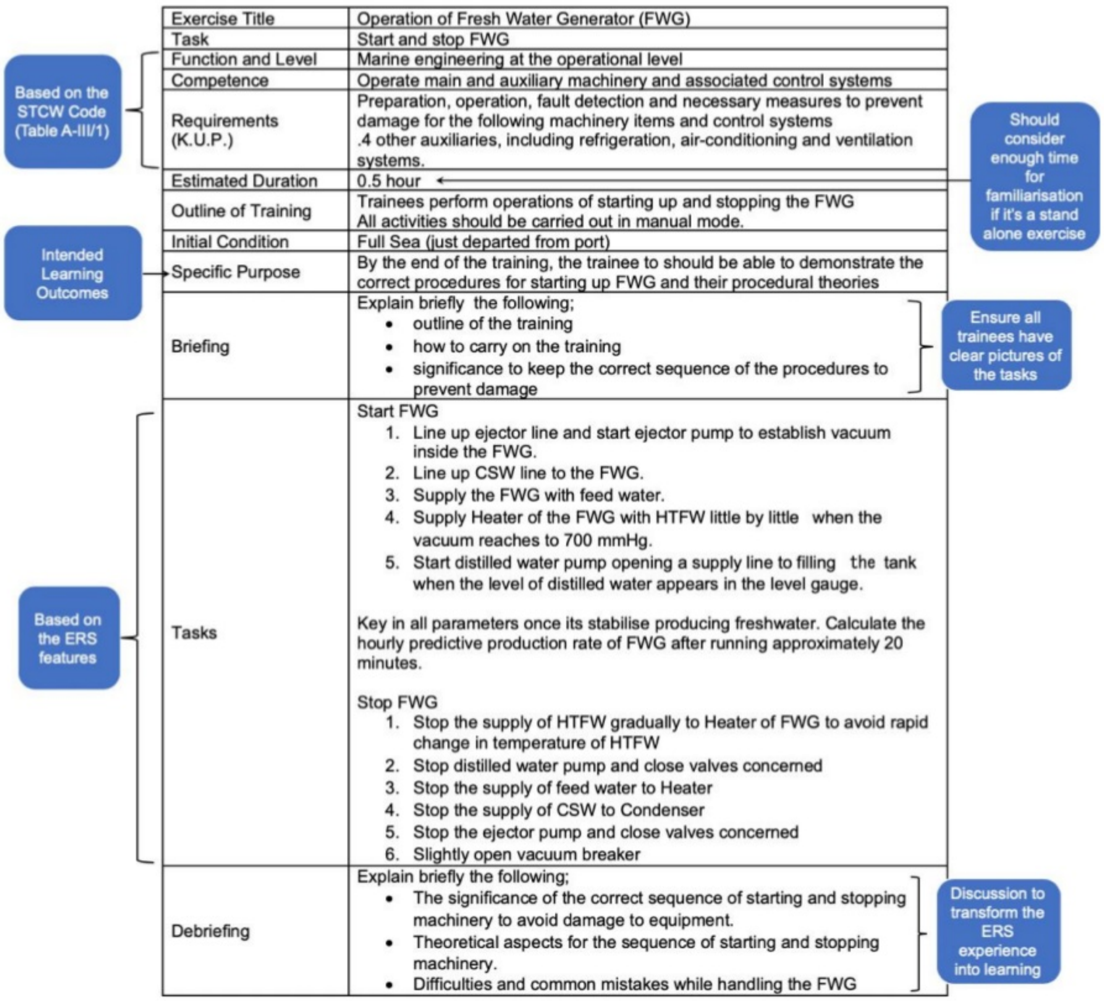
The usage of ERS as a learning tool can only be effective if proper planning has been done from the CDD phase. However, not all ERS trainers were involved in the CDD process. From the study, recruitment of ERS trainers persists as a serious issue. There were possibilities that the course could be designed by one person and delivered by other persons. This might happen if METIs that hire active seafarers as part-time ERS trainers.

In terms of CDD, most countries used IMCs as their guidelines. According to Houghton (2012), *"Some model courses are apparently intended to motivate and encourage some of the less energetic companies and flag states by giving them minimum standards to work to standards which are at the threshold of what is acceptable."* This may result in a lack of proper understanding of their contents due to over-reliance on IMCs' guidelines.

Therefore, the trainer should have a good comprehension of the lesson plan and how the training will be conducted beforehand, regardless of who developed the training module. Figure 13 shows a simple example of an instructor manual sheet, which is a part of the lesson plan.

Figure 13

Sample of instructor manual for ERS exercise



Exercise Title	Operation of Fresh Water Generator (FWG)
Task	Start and stop FWG
Function and Level	Marine engineering at the operational level
Competence	Operate main and auxiliary machinery and associated control systems
Requirements (K.U.P.)	Preparation, operation, fault detection and necessary measures to prevent damage for the following machinery items and control systems .4 other auxiliaries, including refrigeration, air-conditioning and ventilation systems.
Estimated Duration	0.5 hour
Outline of Training	Trainees perform operations of starting up and stopping the FWG All activities should be carried out in manual mode.
Initial Condition	Full Sea (just departed from port)
Specific Purpose	By the end of the training, the trainee to should be able to demonstrate the correct procedures for starting up FWG and their procedural theories
Briefing	Explain briefly the following; • outline of the training • how to carry on the training • significance to keep the correct sequence of the procedures to prevent damage
Tasks	Start FWG 1. Line up ejector line and start ejector pump to establish vacuum inside the FWG. 2. Line up CSW line to the FWG. 3. Supply the FWG with feed water. 4. Supply Heater of the FWG with HTFW little by little when the vacuum reaches to 700 mmHg. 5. Start distilled water pump opening a supply line to filling the tank when the level of distilled water appears in the level gauge. Key in all parameters once its stabilise producing freshwater. Calculate the hourly predictive production rate of FWG after running approximately 20 minutes. Stop FWG 1. Stop the supply of HTFW gradually to Heater of FWG to avoid rapid change in temperature of HTFW 2. Stop distilled water pump and close valves concerned 3. Stop the supply of feed water to Heater 4. Stop the supply of CSW to Condenser 5. Stop the ejector pump and close valves concerned 6. Slightly open vacuum breaker
Debriefing	Explain briefly the following; • The significance of the correct sequence of starting and stopping machinery to avoid damage to equipment. • Theoretical aspects for the sequence of starting and stopping machinery. • Difficulties and common mistakes while handling the FWG

Note. Adapted from *Model course 2.07. Engine-room simulator* by International Maritime Organization, 2017, IMO Publication. Copyright 2017 by IMO Publication.

The vital points in ensuring the effectiveness of the learning process are:

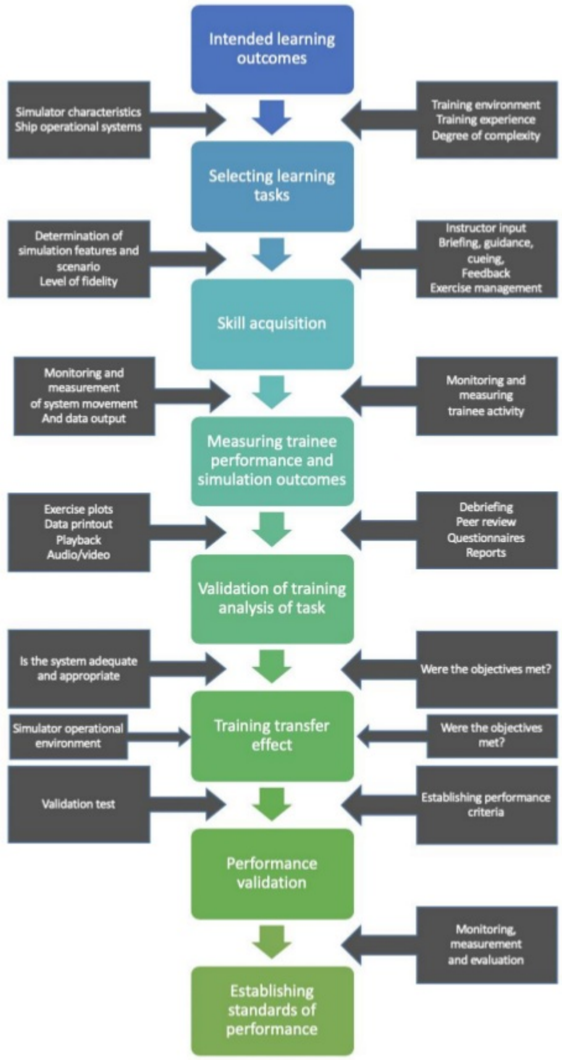
- The STCW requirements
    - This part is to give a clear idea of coverage and scope of the topic which complies with the STCW. If the ERS usage is beyond the STCW requirement, this part might not be significant.

- Time allocation
  - The time should be realistic, especially the familiarity of the learners with the ERS layout. Some allowance for debriefing should be considered as well.
- Intended learning outcomes
  - This part is to keep the trainer and learners focused on the specific objectives of the activity, and help the trainer to realign the learners in case of any deviation.
- Briefing
  - The briefing is important to outline the training and set the shared mental models among the learners. It is important for the learner to know the clear direction and objective of the exercise. The depth of the briefing depends on the background of the learners.
- Tasks during the exercise
  - The trainer should be clear about the steps or procedure of the exercise. It should be tested multiple times and given consideration whether the complexity of the exercise suits the time allocation or not. Exercise sheets may be developed based on the tasks in order to guide the learners. However, a rigid guideline may limit the creativity of the learner to explore other things.
- Debriefing
  - Debriefing should be the most important aspect in ERS exercises as it is the self-reflection of the tasks and helps in clarifying all the doubts. This process is dynamic, as different classes may experience different difficulties. Although there is a technology to provide automated assessment and evaluate the performance of learners, the technology does not teach students how to execute manual tasks or explain whether the task should be done in one way or another (Hindmarsh, Hyland, & Banerjee, 2014). This is where the professional judgements of trainers are very significant to facilitate the learning process.

The lesson plan is not a static process and subjects for improvement. Therefore, it is important for the trainer to perform task analysis and training validation to ensure the exercise meets the objectives and is relevant (Fisher & Muirhead, 2019) (Figure 14).

Figure 14

Key processes in training validation



Note. Adapted from *Practical teaching skills for maritime instructors* by D. Fisher & P. Muirhead, 2019. WMU Publications. Copyright 2019 by WMU Publications.

Nevertheless, the planning process is only based on predictions. The ERS trainers play a significant role in monitoring the actions of the students in the actual learning process. The trainer must be versatile and change the activities based on various factors such as the classroom ambience, the student's circumstances, the intrinsic and extrinsic motivation of the students and the progression of the students during the activities.

Conclusions

The main purpose of this study was to investigate the effectiveness of ERS as a learning tool in MET. This section will revisit each research question and summarise how it was answered.

RQ1: What are the legal and learning frameworks that are currently available to ensure the effectiveness of ERS as a learning and assessment tools?

In terms of legal frameworks, it can be concluded that STCW has provided a comprehensive mechanism in ensuring the effectiveness of the usage ERS under regulations;

- I/6 Training and assessment- Governs the training and assessment quality
- I/12 Use of simulators- Governs the usage of ERS
- I/8 Quality standards- Acts as a feedback loop in ensuring quality

However, the use of ERS is not obligatory under Chapter III (engine department) of the STCW. From the literature review, it was understood that effective governance is partly crucial in ensuring great learning quality outcomes.

In terms of learning frameworks, all dominant learning theories have different philosophies of learning, but understanding them all is beneficial for the learning process. The knowledge of multiple-approaches to learning is important in the learning context.

RQ2: How effective is the current practice as well as the usage of ERS in MET, as a learning tool from the viewpoint of various stakeholders?

From the viewpoints of various stakeholders, it was widely acknowledged that the ERS is the best tool to illustrate the real situation in the ER. ERS provides a low-risk environment, despite the limitations that it may have. The effectiveness of ERS as a learning tool is being monitored and controlled by the MAs, and the majority countries use IMCs as guidelines in designing the curricula. The ERS was viewed by a number of seafarers as primarily accessible to cadets. A different opinion from another seafarer suggested that ERS should be used by all levels, ideally operational-level for technical-skills, and management-level for soft-skills. The majority accepted that ERS might be more useful for specialised training on a specific vessel, as this kind of training has been utilised and established according to the expert from a training ship. Manufacturers of simulators develop a number of inventions to fix various issues such as realism, specialised training, and COVID. The innovations are intended to satisfy the industry's demands.

RQ3: What are the challenges that various parties encounter in regards to ERS?

The most significant challenge in ERS is the financial constraint which has domino effects to other various issues such as hiring trainers, relatively expensive course fees and low demand for non-obligatory ERS training. Apart from that, most seafarers have high expectation for ERS to be sophisticated with a strong degree of realism, which the simulator manufacturers are struggling to satisfy them as there is no single model in ERS that could satisfy all preferences.

RQ4: How can the usage of ERS as a learning tool to be effectively optimised?

Effective governance plays a significant role in ensuring the quality of the METIs. Although each METI should be accountable for its actions, firm governance by the MA may hinder the METI from being slack and taking things for granted.

Different countries may have different circumstances. Therefore, the MAs should be careful in imposing national standards and have to be realistic, according to the capacity of the country. However, the MA should never compromise the quality of the training, which may result in jeopardising the safety of the seafarers due to lack of competence.

The four dominant learning theories underpin the concepts of learning indirectly articulated in the creation and implementation of ERS curricula. The stimuli are significant for learning in behaviourism and can promote learning motivation. The strength of cognitivism is the inclusion of mind operation and involvement of higher-order thinking, which is not addressed in behaviourism. However, constructivism and connectivism appear to be perfect in describing the complicated learning that is required, particularly when it involves trouble-shooting, critical-thinking and exemplary learning. A diverse approach to understanding of learning and behaviour would bring versatility to the ERS programme, thus, maximising the effectiveness of the learning process.

Ideally, ERS is suitable for all levels of comprehension. Since in reality, financial constraints are the major issue, the effectiveness of ERS learning activities strongly relies on the proper planning. The usage of appropriate ERS type, should be compatible with the learning objectives. The targeted students' prior knowledge should be considered. Apart from that, resource management is very crucial to optimise the usage of ERS. The resources involved are time allocation, type of ERS, workforce and cost-involved.

In addition, to optimise the usage of ERS, the trainers should have a clear idea of the lesson plan and how the activities are to be carried out in advance. The lesson plan does not reflect a predetermined cycle and is subjects to change.

Based on the conclusions, some of the recommendations for future research are:

- Optimising the costing of ERS through classroom management.
- Sustainability of maritime simulator training.
- Recruitment programme of ERS trainer.
- Utilising ERS beyond the STCW requirements.

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