



BETTER SHIPS, BLUE OCEANS

Seagoing Service and Simulator Training

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SUMMARY

Background

According to the STCW Convention [Ref 23.], to become eligible for certification, a future seafarer must complete 12 months of seagoing service. Like other IMO member states, the Netherlands applies Article IX of the Convention, which allows the use of equivalent arrangements (EA). This EA stipulates that students trained under the Dutch education system may reduce their required seagoing service by 60 days as part of an approved training programme, provided they complete a dedicated simulator training, with a total duration of 15 days.

Objective and rationale

The objective of this study is to assess the effectiveness of the equivalent arrangement (EA) in terms of simulator training as replacement for a part of the seagoing service as defined in the current STCW Convention.

In short, the education of future seafarers is a combination of theoretical and practical education. Education at the academy in classrooms serves as theoretical education, seagoing service serves practical training and as a third education means, simulators are applied. The question at hand is whether simulator education is of such high values that the seagoing service time can be reduced by simulator education with a certain time ratio.

Method

In order to assess the effectiveness of the equivalent arrangement, a literature review was performed and subsequently ten maritime academies in the Netherlands were visited and interviews were conducted with students, study coordinators and simulator trainers. Training record books were analysed.

Conclusions

Literature and experiences from maritime institutes underline that simulators offer a very valuable educational environment which can be effectively applied to develop competences for navigational officers and marine engineering officers.

Using, high fidelity simulators in the education of maritime officers offers the opportunity to master relevant competencies and knowledge. It supports the understanding and becoming proficient through a structured approach training and evaluating competences in a controlled learning environment. For creating time in a curriculum in order to increase the amount of simulator education it is achievable to reduce seagoing service time since the combination of both simulator education and seagoing service. This is more effective than seagoing service only. More specific, it can be stated that a reduction from 12 to 10 months seagoing service and adding 15 days of simulator training results in an effective, high quality, curriculum.

Simulator education should always be considered in combination with seagoing service, which remains an essential part of the education of a seafarer. This applies for both for navigational officers as well as marine engineering officers. To learn the way of life onboard and to experience applying competences, real world conditions are essential.

Simulator education is by far the most effective way to educate subjects rarely encountered at sea, whereas sea going service hardly offers the opportunity to learn how to act in such rare operational situations.

In addition, simulator technology allows for a more standardised assessing process of students. Increasing the amount of simulator education time and reducing the amount of seagoing service time to less than 10 months seems viable but requires a more in depth study to define the exact minimal durations of both seagoing service and simulator education.

Recommendations

In order to allow maritime institutes to create an effective curriculum based on nowadays insights in educational science and making use of state-of-the-art educational tooling, the STCW Convention should ideally provide room for optimisations within boundaries. The current requirement of 12 months seagoing service might be rephrased by a well-defined bandwidth of possible combinations of seagoing service and simulator education. A baseline of a minimum of 12 months seagoing service without any requirement for simulator education can remain. The possibility of offering a curriculum containing 10 months of seagoing service and 15 days of simulator education should be covered at least. A further reduction of seagoing service and increase of simulator education time is feasible to acquire the required level of competences as defined in the STCW Convention. Exact numbers for minimum duration of seagoing service and simulator education cannot be given based on the study at hand.

The developments in the maritime industry are ongoing and with respect to higher level of automation, remote assistance from ashore, new propulsion systems using new energy sources might require more attention in the education of officers. Simulation might be an essential solution and the effectiveness of seagoing service on two or at least a limited number of vessels might not be sufficient anymore. In the process of reviewing the STCW Convention this topic might require further elaboration.

ABBREVIATIONS & READING GUIDE

CoC	– Certification of Competence
EA	– Equivalent Arrangement
EMSA	– European Maritime Safety Agency
IAMU	– International Association of Maritime Universities
IMO	– International Maritime Organization
MET(I)	– Maritime Education and Training (Institutions)
MSTC	– Maritime Simulation Training Centre
NI	– Nautical Institute TRB – Training Record Book
STCW	– Standards of Training, Certification and Watchkeeping for Seafarers
STR	– Sea Time Reduction

STCW Convention

When the term **STCW Convention** is used, or **Convention**, reference is made to the *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978, as amended in 1995 and 2010*.

Seagoing Service

When reference is made to an onboard internship as required by the STCW Convention, the term **seagoing service** is used.

Equivalent Arrangement, equivalence and equivalency

When reference is made to the application of Article IX of the Convention, the term **equivalent arrangement** is used.

When reference is made to the concept of similarity / substitution as applied by the Convention, the term **equivalency** is used.

When reference is made to the concept of similarity / substitution as a noun, the term **equivalence** is used.

1 INTRODUCTION

1.1 Background

Progress toward proficiency at the maritime academies and colleges is continuously assessed by highly skilled faculty staff. Each student must be found competent in basic skills before advancing to more sophisticated levels of training. How to make sure that a student reaches this level of proficiency is defined in the STCW Convention [Ref 23.]. This Convention defines, amongst others, the amount of seagoing service a student should experience as part of his/her education. This applies both for bridge and engine room students. The Netherlands developed an effective curriculum for the education of maritime students. In the early days of simulation the use of simulator education was integrated in the curriculum. It is the strong belief that simulators increase the quality of education. Even so that it was decided that adding simulator education to the curriculum and reducing the seagoing service of students would, in the end, result in better education for maritime students. The Netherlands has been applying this method since the mid-1990s, and it continues to be used with satisfaction and positive feedback. Therefore the intention is to have this education method be acknowledged in the international community and IMO in specific.

According to the STCW Convention, to become eligible for certification, a future seafarer must complete 12 months of seagoing service. Like other IMO member states, the Netherlands applies Article IX of the Convention, which allows the use of equivalent arrangements (EA). This EA stipulates that students trained under the Dutch education system may reduce their required seagoing service by 60 days as part of an approved training programme, provided they complete a dedicated simulator training, with a total duration of 120 hours.

The equivalence for this arrangement was based on research by TNO [Ref 9.] in 1994 and later Hiemstra et al. [Ref 10.] in 2012. These studies showed that certain competences could be mastered in a shorter time frame on a simulator, and hence a simulator training for seagoing service ratio was decided.

Nowadays, the use of simulators to transfer work-related knowledge and skills to students is widespread, with aircraft simulators serving as a prominent non-maritime example.

Given the fact that simulator-based training has been further refined and developed since 1994 and 2012, and is used now in contexts beyond competence-based training alone, this study will assess the effectiveness of simulator training as part of seagoing service.

1.2 Objective

The objective of this study is to assess the effectiveness of the equivalent arrangement (EA) in terms of simulator training as replacement for a part of the seagoing service as defined in the current STCW Convention.

In short, the education of future seafarers is a combination of theoretical and practical education. Education at the academy in classrooms serves as theoretical education, seagoing service serves practical training and in the middle (see Figure 1-1) we could place simulator training. Through the years simulators are more and more used to alternate theoretical lessons with practical simulator sessions with the goal to bring theory and practical training closer. Literature in the field of educational science proves that a more effective way of educating people is to bring theory and practical training together and more specific the use of simulations is described.



Figure 1-1: The place of simulator training in an educational curriculum

A classical educational trajectory consist of fixed time periods for school-based learning and seagoing service. The widespread usage of simulators, both in school settings and as an equivalent for seagoing service, justifies an approach in which simulator training is evaluated along the following dimensions:

1. **Simulator training is evaluated based on the extent to which it overlaps with seagoing service as an educational tool.**

In which way similarity is found between the intended learning processes offered by seagoing service and simulator training.

2. **Simulator training is evaluated based on the degree to which it adds educational value as part of seagoing service.**

In which way similarity is found in the intended outcomes of seagoing service and simulator training.

1.3 Scope

The scope of the study comprises both the education for Nautical Officers and Marine Engineer Officers. Focus will be solely on the equivalency principle meaning that simulator training can be applied as an enhanced alternative for a part of the onboard internships. The complete curricula for the education of Nautical Officers and Marine Engineer Officers will not be covered.

1.4 Method

The starting point is the development of a conceptual and theoretical framework for seagoing service. A review of the STCW Convention reveals that it does not explicitly define a competency framework for seagoing service (as further discussed in Chapter 3). Therefore, the framework proposed by Mori and Manuel [Ref 16.] has been adopted, as it offers a comprehensive definition of the intended learning process and its corresponding outcomes.

The first evaluation, to which extent simulator training can overlap with seagoing service, focuses on the 'how' of seagoing service and simulator training. It explores the similarity of simulator training in terms of method, structure and learning experience. In addition, this evaluation tries to find in what way simulator training can complement seagoing service in such terms of relevant method, structure and learning experience (i.e. scenario-based learning).

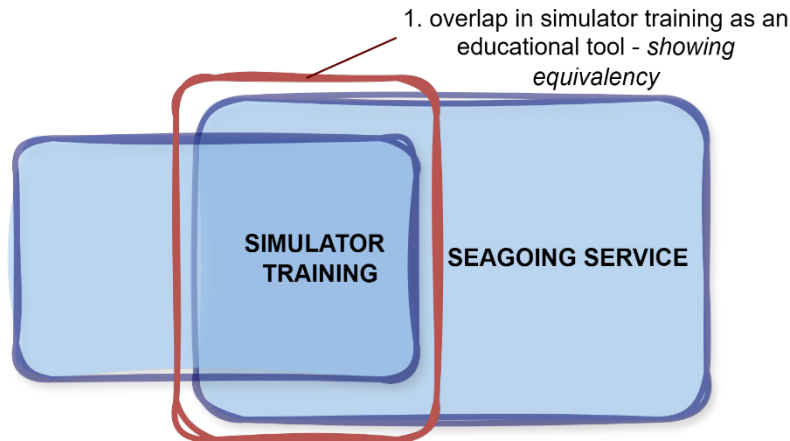


Figure 1-2: *Equivalence of simulator training*

Second, simulator training is evaluated based on the degree to which it adds educational value as part of seagoing service. It focuses on the 'what' of seagoing service and simulator training. It relates to the learning outcomes and what contributes to enhance those learning outcomes.

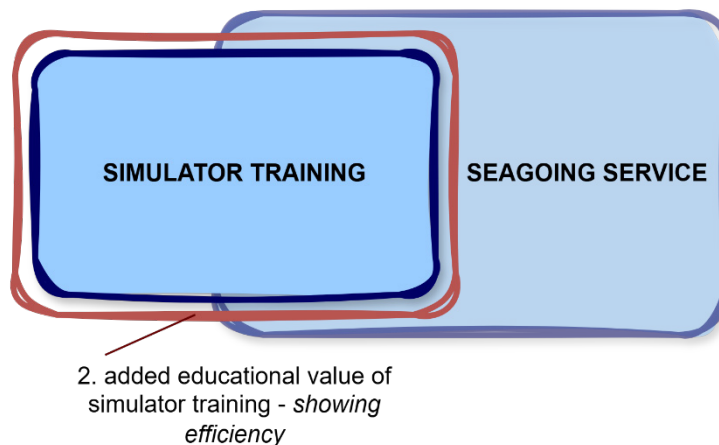


Figure 1-3: *Efficiency of simulator training*

Both evaluations are done by a combination of literature study and visits to maritime academies. Literature study gives both a theoretical background and applications, findings and lessons of simulator use in similar cases. Visits to maritime academies resulted in an evaluation and assessment of both the learning process and learning outcomes of simulator training. The outcome of the literature study is used to describe the results of the visits.

For the literature study, studies related to the simulator as an educational tool, not limited to the maritime domain, are compared to the conceptual theoretical framework for seagoing service. This literature study provides insight in how simulator education should ideally be integrated in a generic curriculum for acquiring competences for a high risk job. In addition the use of simulation in the training in various domains provided insights in effectiveness of simulator training and the combination of simulator training and on the job training.

Maritime academies were visited and interviews were conducted with students, study coordinators and simulator trainers. During the interviews, students were also asked to fill in a questionnaire. The STCW Convention and the literature study served as basis for the questions asked and to evaluate the usage of simulator training and application of seagoing service at the maritime academies visited for this study.

The literature study identified a best way how to, theoretically, apply simulator training across various domains. The visits and interviews resulted in a qualitative analysis of the efficiency and equivalence of simulator training and seagoing service as currently applied in the Netherlands.

First, simulator training demonstrated equivalence in the learning process, and specifically it showed the effectiveness of learning transfer of relevant knowledge, skills and attitudes in handling complex scenarios and emergency situations. These findings were supported by the outcomes of the questionnaire.

Second, simulator training demonstrated to be efficient in acquiring the overall standard of competence by enhancing the performance of students. Together, these findings provide a foundation to plead for a combination of simulator education and seagoing service as part of a curriculum for both Nautical Officers as well as Marine Engineer Officers.

2 CONCEPTUAL THEORETICAL FRAMEWORK FOR SEAGOING SERVICE

In their paper “An Exploration of the Theoretical Foundations of Onboard Seafarer Training: A Systematic Review of the Literature”, Mori and Manuel recognise the varying implementations and approaches to onboard seafarer training across different IMO jurisdictions. According to their analysis, these differences are largely shaped by distinct historical, cultural, and institutional factors. In response to the need for a common theoretical underpinning of onboard training, something they found lacking in the STCW Convention, their study resulted in the following definition for onboard training:

(Onboard training is:) “an expression of career-related apprenticeship in the maritime industry (ship operation) where an individual/learner/novice is immersed in a learning process situated in the operational reality of a community of practice (CoP) exhibiting a high degree of materiality and where the individual’s learning, while being self-driven/self-directed, is framed by the influence of “more knowledgeable others”, mentoring structures and institutional support that together facilitate the movement of the novice from the periphery of the CoP to its core through the acquisition and continuous development of relevant positive knowledge, skills and attitudes”. [Ref 16.]

In search for a solid, holistic starting point for evaluating the use of simulators, a review the STCW Convention led to similar conclusions. Therefore, the definition and conceptual theoretical framework proposed by Mori and Manuel is adopted.

The conceptual theoretical framework, as illustrated in Figure 2-1, serves as a guiding structure for evaluating and comparing seagoing service and simulator training within the maritime domain.

The framework is further elaborated across three chapters (the red boxes in Figure 2-1). **Chapter 3** outlines the legal standards and requirements for seagoing service and simulator training as defined in the current STCW Convention. **Chapter 4** explores the theoretical foundations of onboard training, presenting studies that demonstrate how simulator training aligns with learning theories and domains essential for effective onboard learning. **Chapter 5** evaluates simulator usage and seagoing service experiences by means of in depth interviews and a questionnaire. The findings are analysed in relation to the factors ‘*neutralizing or enhancing practical and environment factors*’, ‘*structures, policies, and arrangements*’ and factors concerning the individual student, ‘*motivation and self-directedness*’. This approach enables a holistic evaluation of simulator usage and onboard training, considering not only competencies but also learning processes, attitudes and external influences.

The results of this evaluation are discussed in **Chapter 6**, which addresses the equivalence of simulator training in terms of the *how*—its similarity and added value in learning methodology—and the *what*—its ability to achieve the intended outcomes, potentially in a more effective manner.

Finally, **Chapter 7** presents the conclusions and recommendations.

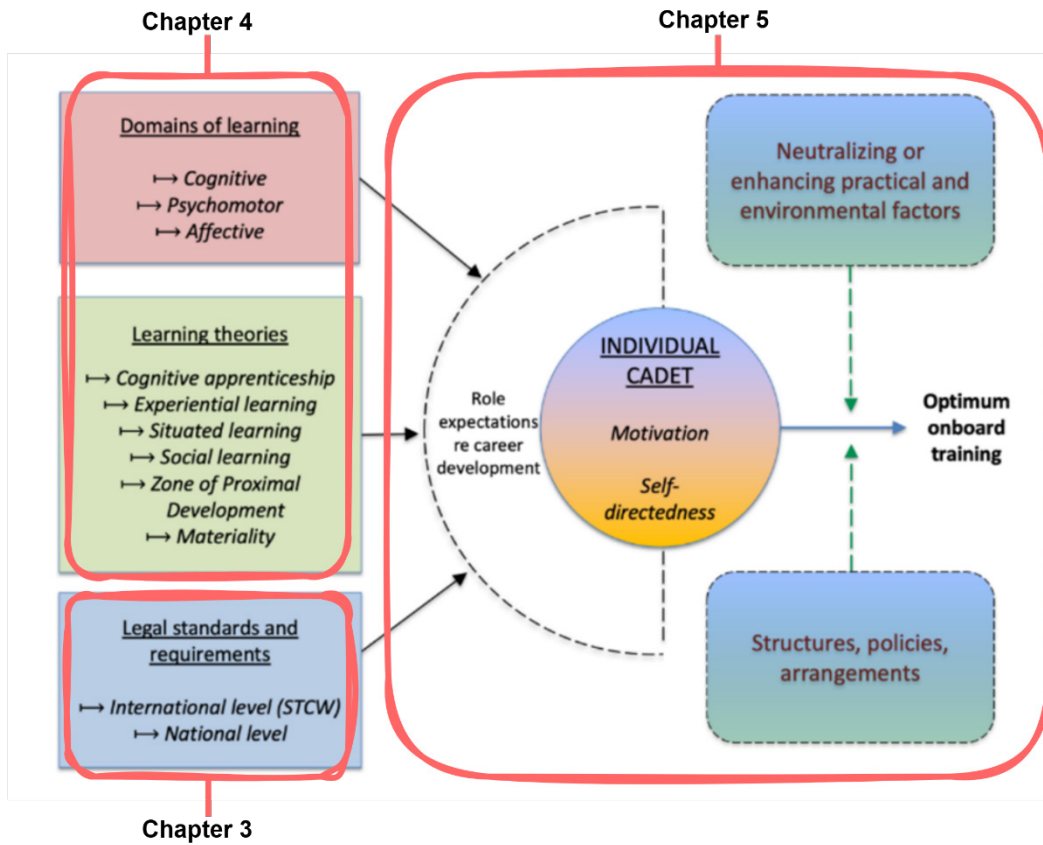


Figure 2-1: Conceptual theoretical framework Mori and Manuel [Ref 16.], red boxes added by MARIN

3 REGULATORY FRAMEWORK

3.1 IMO and STCW Convention

The International Maritime Organization (IMO) is a United Nations specialised agency with responsibility for the safety and security and the prevention of marine pollution by ships. The IMO provides and maintains a regulatory framework.

The IMO is responsible for more than 50 international conventions and agreements. Relevant for maritime education and therefore this study is the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW).

Seagoing service

The STCW Convention stipulates that every student in order to get qualified as an officer in charge of a navigational or an engineering watch (CoC, certificate of competence) needs to have completed at least 12 months of seagoing service, in which the student conducted at least 6 months relevant watchkeeping duties.

The STCW Convention provides requirements and guidance, particularly regarding seagoing service. However, these requirements are broadly defined. For the relevant competencies listed in Table A-II/1 and Table A-III/1, Column 3 indicates that nearly every competence can be assessed and examined using simulator training. This means that seagoing service is just one method of demonstrating competence. The tables do not define seagoing service as a mandatory 12-months period during which specific competencies must be mastered and demonstrated.

The 12-months requirement is intended for practicing and acquiring skills, without predefined specific learning outcomes. Therefore, using the learning outcomes from Tables A-II/1 and A-III/1 as a benchmark to compare simulator training with seagoing service is debatable. Any claim that simulator training is more effective because it allows for a shorter timeframe to demonstrate a certain competence can be objected by:

- The STCW Convention already allows for the use of simulators for assessing that relevant competence.
- The 12-month period is not defined for (and thus designed to accelerate) specific competence acquisition, but rather to ensure continuous practice, skill development, and engagement in relevant tasks and duties.

Ultimately, the Convention emphasizes the importance of the training process itself in the context of seagoing service, rather than focusing solely on the speed of competence acquisition and demonstration. This perspective is echoed by Hiemstra et al. [Ref 10.], who affirm in their research the effectiveness of simulator-based competence development for Marine Engineering Officers. However, they also note that the implications for seagoing service remain difficult to define, as the structure of a seagoing service is not primarily designed to facilitate rapid competence acquisition. The limitations of the STCW Convention as a comprehensive competency framework become particularly apparent in research addressing emerging developments in maritime shipping, e.g. autonomous shipping [Ref 21.] and alternative fuels and energy systems [Ref 22.]. These innovations introduce new competence requirements that challenge the Convention's capacity to adapt and integrate evolving industry needs. Both studies conclude that a combination of different methods may be the most effective for acquiring new competences.

However, where the Convention does not define the mandatory seagoing service in terms of the individual competencies listed in Table A-II/1 and Table A-III/1, it does express—through the Guidance (Section B-II/1 – 3 and Section B-II/1 – 14)—the objective of achieving the overall standard of competence. This overall standard is further described as being more than the immediate technical requirements of the job or the specific skills and tasks to be performed. It is intended to reflect the broader dimensions necessary to meet the full expectations of competent performance as a ship's officer. This includes relevant knowledge, theoretical understanding, principles, and cognitive skills that underpin all levels of competence. Moreover, it encompasses proficiency not only in what to do, but also how and when to do it, and why it should be done.

The 12-months seagoing service thus serves as a time to practice, exercise and acquire skills and duties to achieve the overall standard of competence required. This overall standard of competence represents more than the sum of the competencies outlined in the tables, it also encompasses, in addition to skills and knowledge, relevant positive professional behaviours and attitudes. This corresponds to the phrase “... *the acquisition and continuous development of relevant positive knowledge, skills and attitudes*” from the definition for onboard training by Mori and Manuel [Ref 16.].

In the end, the STCW Convention is clear in its standards and guidelines about seagoing service in the following elements:

- **Organisational:** 12 months seagoing service needs to be part of approved training programme which is documented in a training record book and supervised by qualified officers. Training objectives needs to be clearly stated. The training programme on board needs to be planned and structured. Every candidate receives an induction aboard the vessel.
- **Tasks and duties:** 12 months to undertake tasks and duties of an officer in charge of an engine-room watch or navigational watch, for the latter ,these are further specified in the Guidance, and include tasks and duties related to steering systems, general seamanship, mooring, anchoring and port operations, life-saving and fire—fighting appliances, systems and equipment, cargo work, bridge work and watchkeeping (for at least 6 months) and engine-room familiarisation.
- **Goal:** achieving the overall standard of competence required. This overall standard of competence needs to be as such, that officers can work competently in different ships and across a range of circumstances, anticipate, prepare for an deal with contingencies, and adapt to new and changing requirements.

Standards of training and assessment

Regulation I/6 and the corresponding Section A-I/6 of the STCW Convention describe standards of training and assessment. Training and assessment needs to be structured in accordance with written programmes, and needs to be conducted, monitored, evaluated and supported by qualified and properly instructed persons, whether it is onboard a vessel or in a training institution. However, for persons conducting in-service training or assessment on board a ship, this task is not allowed to affect the normal operation of the ship, and shall only be done when they can dedicate their time and attention.

Persons conducting in-service training of a seafarer, using a simulator, need to have received appropriate guidance in instructional techniques involving the use of simulators, and need to have gained practical operational experience on the particular type of simulator being used.

Simulators

Regulation I/12 and the corresponding section A-I/12 the STCW Convention describe the performance standards of a simulator. In these parts of the STCW Convention a clear distinction is made in using a simulator: 1. for training, 2. for assessment of competency, and 3. for demonstration of continued proficiency.

Additionally, in Section B-I/12, guidance is given for conducting training and assessment with simulators. In more detail mandatory radar and ECDIS training is described, including learning objectives. In less detail performance standards are described for navigation and watchkeeping, ship handling and manoeuvring, cargo handling and storage, reporting and radio communications and main and auxiliary machinery operation simulators.

3.2 Legislation in the Netherlands

The Netherlands make use of the equivalent arrangement under article IX of the STCW Convention. This article reads as follows:

The Convention shall not prevent an Administration from retaining or adopting other educational and training arrangements, including those involving sea-going service and shipboard organization especially adapted to technical developments and to special types of ships and trades, provided that the level of sea-going service, knowledge and efficiency as regards navigational and technical handling of ship and cargo ensures a degree of safety at sea and has a preventive effect as regards pollution at least equivalent to the requirements of the Convention.

The equivalent arrangement is used in replacing seagoing service partially with simulator training. This is applied to the prescribed seagoing service in STCW regulation II/1 (officer in charge of a navigational watch) and regulation III/1 (officer in charge of an engineering watch).

These equivalent arrangements are communicated in:

- STCW.2/Circ.7 – Simulator training as an equivalency for approved sea-going service as part of the internship period for dual certificated students;
- STCW.2/Circ.55 – Simulator training as an equivalency for approved sea-going service as part of the internship period of engine room students.

3.2.1 STCW.2/Circ.7

STCW.2/Circ.7 mentions an equivalent arrangement for dual certificated students. When several criteria have been met, for example a certain level of automation and actual time spent by the student in the simulator, required seagoing service can be exchanged by simulator service. The mentioned seagoing service refers to the seagoing service as prescribed by requirements of regulations II/1 and III/1. The following are the exchange rates:

1. 5 days of simulator training, half of which has taken place in a full mission bridge simulator and the other half in a full size engine room simulator, may be counted as the equivalent for 15 days of seagoing service;
2. 10 days of simulator training, half of which has taken place in a full mission bridge simulator and the other half in a full size engine room simulator, may be counted as the equivalent for 30 days of seagoing service; and
3. 15 days of simulator training, half of which has taken place in a full mission bridge simulator and the other half in a full size engine room simulator may be counted as the equivalent for 60 days of seagoing service.

Furthermore the simulator has to meet the relevant requirements as defined in regulation I/12 and sections A-I/12 and B-I/12 of the STCW Convention.

3.2.2 STCW.2/Circ.55

The wording of the circular is highly similar as the wording of above mentioned circular. The difference is that it refers solely to the seagoing service requirements of regulation III/1 relevant for an aspirant officer in charge of an engineering watch. This results in the following exchange rates for the equivalent arrangement:

1. 5 days of simulator training, which has taken place in a full size engine room simulator, may be counted as the equivalent for 15 days of seagoing service;
2. 10 days of simulator training, which has taken place in a full size engine room simulator, may be counted as the equivalent for 30 days of seagoing service; and
3. 15 days of simulator training, which has taken place in a full size engine room simulator, may be counted as the equivalent for 60 days of seagoing service.

3.2.3 MSTC

The equivalent arrangements applied in the Netherlands are implemented through three simulation modules. The first module, referred to as Module 1, consists of five days (40 hours) of simulator training and is conducted using the simulation equipment available at the maritime academies themselves.

Module 1 must be completed prior to participating in the subsequent training weeks at the Maritiem Simulatie Trainingscentrum (MSTC), a dedicated simulation trainings centre located at Terschelling.

Module 2 comprises five days of training at the MSTC and includes bridge, engine room, and cargo simulator exercises. Both bridge and engine room simulator sessions follow a structured format consisting of a briefing, execution (simulation), and debriefing.

Module 3 also spans five days at the MSTC. During this module, students either train on the bridge and cargo simulator or on the engine room and cargo simulator, depending on their specialization.

4 LITERATURE STUDY

4.1 Introduction

Using simulators in the educating and training of professionals operating in complex and high-risk working environments is well-established. For decades, simulation has been a common practice not only in the maritime industry but also in other industries such as aviation. This chapter provides an overview of the literature concerning the application of simulation in educational systems and its effectiveness.

Given the extensive body of literature available, this study has chosen to include, among other sources, several literature reviews that themselves synthesize findings from dozens of underlying studies. The chapter begins with an exploration of learning theories widely applied across various domains. These theories emphasize the integration of theoretical education with practical skill development within educational systems, and this approach is found to be particularly relevant for professions involving demanding, practical tasks.

For each source discussed in this chapter, a dedicated section presents the reference details, a brief summary, and an explanation of its relevance to the scope of this report.

4.2 Learning theory

4.2.1 Four Components Instructional Design (4C/ID) method

Title: Ten Steps to Complex Learning, A Systematic Approach to Four-component Instructional Design
Authors: J. G. Merriënboer and P. A. Kirschner
Organisation: University Maastricht, the Netherlands
Year of publication: 2012 (revisions up to 2024)
Type of literature: Book

Summary:

Merriënboer and Kirschner describe in their book *“Ten Steps to Complex Learning”* a methodology (training blueprint) aimed at developing competencies in complex training situations. This method aligns with High Impact Learning [Ref 18.], respects the various learning domains of Kolb [Ref 2.], and reduces the risk of fragmentation. This book can be seen as a widely applied method in various industries and a standard in educational science.

Merriënboer and Kirschner’s training blueprint consists of four components: learning tasks, supportive information, procedural information and part task practise. Its foundation is formed by so-called authentic learning tasks, in which professional practice is central. These learning tasks include a number of exercises with high variation, and the support provided gradually decreases per exercise. A set of exercises within a learning task is based on the amount of theory needed to solve the problem using a specific strategy. The focus is primarily on higher-order cognitive skills such as analysing and generalizing.

Within these learning tasks, a distinction is made between non-recurrent skills and recurrent skills. Non-recurrent skills use the same type of information but are applied in different contexts. These are knowledge-based tasks that require mental models (for task execution) and cognitive strategies (for taking action). To support this, supportive information is provided in advance so that learners can process interactions and connections. This concerns often specific procedures or operational limits. During exercises, this knowledge is retrieved from long-term memory. The development of non-recurrent skills requires a high degree of variation in exercises to build more generic knowledge.

Recurrent skills, on the other hand, rely on using certain knowledge in a consistent way. These are rule-based activities, where experts have developed procedures for specific actions. The procedural information needed for these tasks concerns how routine aspects should be carried out and is provided just in time, when it is needed.

Finally, it may be necessary to automate certain subtasks. This part-task practice can only be conducted after the subtask has been introduced within the broader context. Without this contextualisation, automating subtasks would result in fragmentation. Figure 4-1 summarises the 4C/ID method.

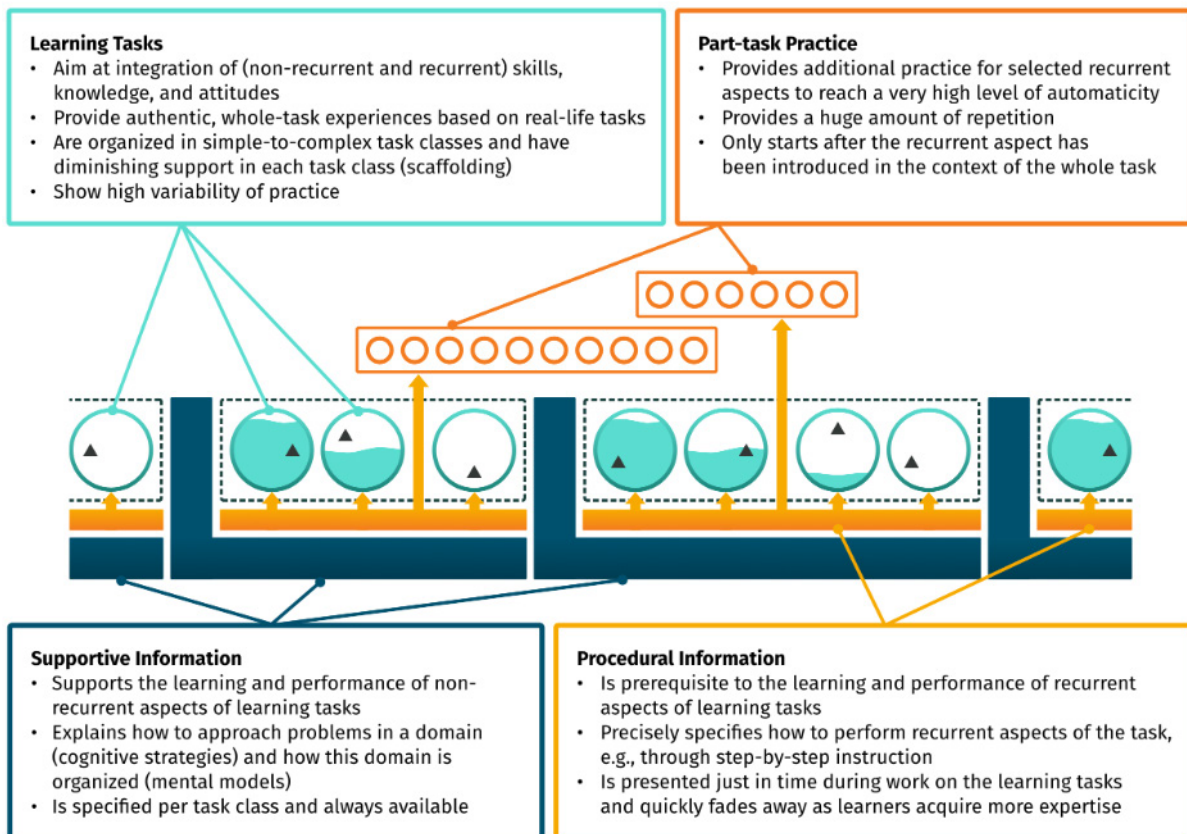


Figure 4-1: Four Components Instructional Design method, 4C/ID

Applying the 4C/ID method in simulator education results in that the trainee receives theory (supportive information) dedicated to a specific part of the operation. Next, the trainee receives procedural information required the operation at hand, such as operational limits. During a first run on the simulator the instructor is available to support and help the trainee as much as possible. During the next run the instructor play a less prominent role and finally the trainee performs the task without any help. In this way the simulator is used in a productive way to stepwise learn the trainee performing a task solo. A simulation environment is ideal for such an iterative learning experience with increasing task complexity and decreasing instructor support.

Relevance for this study:

The 4C/ID theory defines an optimal learning strategy in technical jobs. It describes how complex tasks can be educated by bringing theoretical learning and practical skills together and how an instructor support the trainee in this learning process. A simulator is an ideal learning environment for this 4C/ID method of education.

Simulation-based training has proven effective in achieving the overall standard of competence, particularly because it supports iterative learning. This allows learners to progressively master complex tasks through repeated exposure, feedback, and reflection.

4.2.2 Simulations: Bringing the benefits of situated learning to the traditional classroom

Title: Simulations: Bringing the benefits of situated learning to the traditional classroom
Authors: L. M. Lunce
Organisation: University of North Texas, USA
Year of publication: 2006
Type of literature: Conference paper, literature review

Summary:

Lunce presents educational simulations as a methodology for providing some aspects of situated learning in the traditional classroom. Situational learning is a model of learning in a community of practice. Such a community of practice serves as a learning environment where students learn not only technical skills but also norms, behaviour and values. A simulator environment including instructors and fellow students can be seen as such a community of practice where learning takes place in a relative safe environment. This means that errors can be made and corrected, students learn from each other and instructors who have the supervision, both on technical and non-technical skill acquisition of the group of students.

Relevance for this study:

The study highlights that a simulation environment is an effective tool for developing both technical and non-technical skills. Within this setting, a group of students and an instructor can form a community of practice that supports the individual learning process through shared experience and collaborative reflection.

The study further demonstrates that simulators can serve as a modality for situated learning, closely mirroring the learning dynamics found onboard a vessel. However, simulation offers a more controlled and forgiving environment, allowing learners to engage with complex scenarios without the immediate risks associated with real-world operations.

4.2.3 Simulator Fidelity and Learning

Title: Developing a negotiation simulator with focus on Fidelity, Transfer and Cognitive Involvement
Authors: P. A. Lundebj
Organisation: Department of Psychology, University of Oslo
Year of publication: 2007
Type of literature: Masters thesis

Summary:

This master's thesis investigates how simulator training supports learning across varying levels of human cognitive functioning. It emphasizes the importance of differentiating simulator types based on the nature of the skills they aim to develop. This can range from simple motor tasks to complex cognitive skills such as negotiation and decision-making.

Central to the analysis is Rasmussen's SRK taxonomy, which categorizes human performance into three levels: skill-based behaviour (SBB), rule-based behaviour (RBB), and knowledge-based behaviour (KBB). These categories are used to examine how simulator design can align with cognitive demands, particularly in relation to fidelity, the degree to which a simulation replicates real-world conditions.

The thesis concludes that the relationship between learning and fidelity is non-linear and context-dependent. High fidelity does not automatically lead to better learning outcomes; instead, the effectiveness of simulator training depends on how well the design supports the learner's cognitive engagement at the appropriate SRK level.

Ultimately, simulator training is presented as a powerful tool for skill acquisition, provided it is thoughtfully designed. The SRK taxonomy offers a valuable framework for aligning simulator types with learning objectives. Designers are encouraged to move beyond traditional models of learning as fact accumulation and instead create environments that foster reflection, experimentation, and self-directed learning.

Relevance for this study:

The research shows that simulator training can be a powerful tool for skill acquisition, and therefore effective in achieving the overall standard of competence. It also provides insight in how simulator training can be a more effective method for learning specific skills than seagoing service, in terms of fidelity and materiality.

4.2.4 Scenario-based learning

Title: Mastering Skills in an Unpredictable World
Authors: Niklas Olssen
Organisation: Luleå University of Technology, Department of Social Sciences, Technology and Arts
Year of publication: 2024
Type of literature: Doctoral thesis

Summary:

This doctoral thesis investigates how simulator training can improve train driver education in Sweden, particularly in preparing drivers for abnormal situations that are rarely encountered during real-world internships. The study highlights that while shunting scenarios are commonly practiced, many critical situations, such as signal failures, ATP malfunctions, and level crossing issues, are not sufficiently covered during on-the-job training. This lack of exposure poses a challenge for educators aiming to ensure drivers are adequately prepared for unpredictable events.

Simulator training, especially using low-fidelity simulators with high functional realism, proves to be highly effective. It allows for repeated practice in a controlled environment, which enhances driver performance and reduces errors. The research confirms that performance in simulator tests correlates with actual driving performance, validating the use of simulators for both training and assessment.

Based on these findings, simulator training should be widely implemented to provide practical experience in handling abnormal situations. To optimize its effectiveness, a simulator test should first identify which scenarios a trainee lacks experience in. Additionally, visual behaviour training should be incorporated to improve drivers' ability to maintain external focus, particularly in high-risk areas like level crossings and stations. This approach would enhance situational awareness and reduce the likelihood of collisions and other safety incidents.

In conclusion, the thesis advocates for a structured, simulator-supported training model that combines scenario-based practice with attentional strategies to better prepare train drivers for the complexities of modern rail operations.

Relevance for this study:

This study adopts in part the same methodology as this research, by assessing internships of novice learners in combination with simulator training. The findings underscore the importance of extensive simulator use to provide practical experience in handling abnormal situations. A medium-strong correlation was identified between internship performance and simulator test results, supporting the validity of simulation-based assessment.

The results demonstrate that simulator training is highly effective for scenario-based learning. In this way, it can serve as a valuable complement when seagoing service lacks opportunities to expose trainees to relevant or critical situations.

4.3 Simulator training in the maritime domain

4.3.1 Training to become a master mariner in a simulator-based environment

Title: Training to become a master mariner in a simulator-based environment
Authors: C. Sellberg
Organisation: Göteborg university Sweden
Year of publication: 2017
Type of literature: conference paper

Summary:

In higher education programmes that aim to prepare students for professional performance in safety-critical work activities, the introduction of simulators is seen as a fundamentally restructuring of the ways in which professional skills are developed and assessed. This study focuses on how the use of simulator technologies is restructuring the ways in which maritime work practices are taught and learned. Using a simulator in the maritime education allows students to perform tasks which are onboard only feasible for highly experienced mariners. For example crossing the confined and trafficked waters of the Dover Strait in restricted visibility. As the students' professional vision develops, the instructor gradually decreases this instructional support, while still being attuned to when instructional support is needed.

What the simulator offers is something quite different than learning work practice on board a seagoing vessel, since both the conditions and the primary goal of the activities differ. On board a vessel, the primary goal is to navigate the vessel in a safe way. In the simulator, the primary goal is to learn to navigate any vessel in a safe manner in a setting that allows exploration, experimentation and mistakes.

Sellberg mentions that the realism in the simulator environment relies also on the instructors' ability of connecting simulated events with work practices on board a vessel at sea. Ideally connecting it to students' prior experiences with on board practice increases the learning value.

What makes the simulator such a useful boundary-crossing artefact between training and work is that it is designed to be a realistic training context that fits into existing work practices in the maritime domain. At the same time, it is rather open and, thus, allows for flexible use. Hence, learning how to simulate is, in its own right, a professional skill required in the maritime industry that deserves more attention. For example, monitoring technologies in the instructor's room, which enable the instructor to make on-going assessments and, in turn, to provide students with the instructional support necessary to achieve learning objectives is important. Also include technologies for debriefing, such as scenario playbacks that make prior actions accountable and, thus, enable post-scenario discussions, reflections and assessments of the events that are played out in the simulator.

Sellberg concludes with: It is also important to emphasise that simulator-based training should not fully replace time at sea. Rather, to ensure that students can relate between practices, simulator-based training should be combined with periods of apprenticeship on board a vessel.

Relevance for this study:

This study illustrates how students can engage with complex tasks in a simulator that would be too risky to perform onboard a vessel. It emphasizes that actively performing a task offers a significantly more effective learning experience than merely observing a senior colleague. Furthermore, it acknowledges that simulator-based education cannot replace onboard training; rather, a combination of both is essential.

The findings suggest that integrating simulator training with seagoing service provides a more effective approach to learning and experiencing complex tasks than relying solely on seagoing service.

4.3.2 Impact of Simulation Fidelity on Student Self-efficacy and Perceived Skill Development in Maritime Training

Title: Impact of Simulation Fidelity on Student Self-efficacy and Perceived Skill Development in Maritime Training
Authors: S. K. Renganayagalu, S. C. Mallam, S. Nazir and P. Haavardtun
Organisation: University of Southeast Norway, Borre, Norway
Year of publication: 2019
Type of literature: journal article on experimental research

Summary:

This paper describes the use of simulations for maritime education on various levels of fidelity for engine room simulation. It concludes that the two levels of fidelity contributed to the training effectiveness of the students, though handling the Virtual Reality goggles and application caused some students difficulties handling it. In other words, fidelity level of the simulation and the way the simulation is being operated positively affected reported self-efficacy and perceived skill development. Self-efficacy acquired before or during training, leads to more motivation to learn and better learning outcomes.

Relevance for this study:

The level of fidelity, or in other words, the degree of immersion with which simulators replicate reality, is an important consideration when using simulation as a training environment. Additionally, this study highlights the significance of self-efficacy as an affective learning outcome, influencing a student's task selection, performance level, and the effort invested in learning. These insights support the conclusion that simulator training, when combined with seagoing service, offers a more effective learning approach than seagoing service alone.

4.3.3 A comparative study of training methods for training and education of marine engineering students

Title: A comparative study of training methods for training and education of marine engineering students
Authors: I. Cicek, C. Deniz, A. Kusoglu, and T. Nakazawa
Organisation: Istanbul Technical University Turkey and Kobe University of Mercantile Japan
Year of publication: 2001
Type of literature: conference paper on experimental research

Summary:

This study concerns a comparison between training onboard a commercial vessel, onboard a training vessel and thirdly in an engine room simulator. The goal of this study was not to define which training environment is best suited but merely to support maritime institutions to decide upon their training types.

A conclusion was that simulation-based training can better support the sharing of experience between trainer and candidate by allowing the trainer to enhance their knowledge and permit it in software built from the same acquirement space. Simulators are genuine educational implements as they allow the collaboration of multiple related areas within maritime education to get involved in the use of knowledge to predict reality and create learning equipment that represents it.

The seafaring officers can be made more competent and skilled in their responsibilities and performance. The curriculum should also aim to meet the mandatory minimum requirement of the navigational function under the STCW Convention for the various levels of responsibility. The curriculum should be used as a teaching guide for all maritime institutions to develop individual simulator-based training courses for seafarers' competency, and the development of the proposed curriculum should combine separate subjects into one consolidated curriculum, balancing classroom and simulator hours.

Students have a positive attitude towards the necessity and progress of simulator training. The students' positive view of simulator training is a valuable factor for the success of that type of education. It requires them to care more about the simulator training, which should be considered when preparing training programmes.

Relevance for this study:

This comparative study between onboard vessel training and engine room simulator training demonstrates the added value of simulation-based learning. One key advantage is that trainees can engage with complex or high-risk scenarios without the danger of damaging real equipment. More importantly, simulator environments foster the development of a strong safety culture, which contributes to reducing human error. Additionally, instructors are able to closely monitor trainee behaviour, providing targeted feedback and guidance throughout the learning process.

The study demonstrates that simulator training can effectively complement seagoing service, particularly in the training of high-risk scenarios. It enables students to practice and gain experience in situations that cannot be safely replicated during seagoing service, thereby enhancing the overall learning process.

4.3.4 The Dutch perspective on the use of simulators and sea time reduction in Maritime Education and Training

<u>Title:</u>	The Dutch perspective on the use of simulators and sea time reduction in Maritime Education and Training
<u>Authors:</u>	W. Uitterhoeve, D. van Heel, P. Werner, H. van der Ende
<u>Organisation:</u>	MARIN (Maritime Research Institute the Netherlands) and MSTC (Maritime Simulation and Training centre Terschelling) the Netherlands
<u>Year of publication:</u>	2018
<u>Type of literature:</u>	report applied research

Summary:

In a study performed for the Ministry of Infrastructure and Water management an overview of (inter)national legal framework is made with a focus on the Dutch interpretation of STCW guidelines regarding sea time reduction. This interpretation is compared with interpretations of some other countries. An inventory of the use of simulators in The Netherlands showed that its use is widespread in both education and professional training. In depth interviews with relevant stakeholders and additional research on trends and developments shows for instance an increased awareness of safety and the importance of the human factor. Recommendations to improve future maritime training include the use of simulators in blended learning environments, taking into account organisational and educational aspects in the design of training. Also the inclusion of higher cognitive skills like decision making and the addition of human factor measurements to objectify human behaviour are examples. Finally, the development of an individual continuous learning line with assessments as guiding moments for further development is mentioned.

Sea time reduction to simulation training is not specifically regulated by the IMO in the STCW guidelines. In dynamic positioning training, aviation and other transport branches it is common to use simulation to reduce practical training. The Netherlands have almost 25 years of experience of STR in MET. It is proven that some competences can be trained better in simulators than in practice e.g. emergency manoeuvres and human resource training. Other aspects are better experienced on board. We argue for a balanced blended learning programme combining the benefits of theoretical (e-learning) lessons, simulator training and on board experience.

Relevance for this study:

This study discusses the Dutch maritime education system which includes simulator education. It concludes that simulator education provides a better training environment than onboard training regarding training emergency situations and human resource training (BRM and ERM). It stresses that a combination of simulator training and onboard training is important to offer a complete training.

4.3.5 Simulator time and its sea time equivalence, , MSR and TNO the Netherlands

Title: Simulator time and its sea time equivalence
Authors: J. M. Schraagen
Organisation: Marine Safety International (MSR) and TNO Human Factors Research Institute, The Netherlands
Year of publication: 1995
Type of literature: report applied research

Summary:

In 1994 and 1995 a study was performed by MSR and TNO Human Factors Research Institute to determine the amount of simulator training required to compensate for 30 days of sea time. The performance of two groups of navigation students was compared. One group followed three weeks of simulator training, the other group six months of seagoing service. For both groups the learning curve was determined based on respectively their performance in the simulator for the first group and the workbook analysis for the second group. Both groups were assessed in identical simulator assessments runs. During these simulator assessments the score on performance criteria was higher for the simulator group (83% versus 53% for the sea going group). Also the time needed to reach the same level of performance was shorter for the simulator group (190 hours instead of 310 hours for the sea going group).

Based on the constructed learning curves it was determined that 60 days of seagoing service was equivalent to 120 hours simulator training time.

Relevance for this study:

This research establishes that 120 hours of simulator training is equivalent to 60 days of onboard training, while still requiring 10 months of seagoing service. The findings demonstrate that competencies can be effectively acquired through simulator-based training.

4.3.6 Effectiveness of simulator training, the effect of simulator training and seetime on the skill development of maritime engineers

Title: Effectiveness of simulator training, the effect of simulator training and seetime on the skill development of maritime engineers
Authors: F. Stiekema, P. Werner, D. Hiemstra, H. Hummel
Organisation: Maritime Institute Willem Barentsz and NHL Hogeschool, the Netherlands
Year of publication: 2012
Type of literature: report applied research

Summary:

In 2012 a study was conducted by the Maritime Institute Willem Barentsz into the 'Effectivity of simulator training' for maritime engineers. The objective was to assess the development of maritime engineering students during simulator training and during the student trainee work placement on-board. In advance both teachers and mentors onboard expected competence development using simulator training as faster compared to onboard experience. A comparison of the performance of two groups of students with and without simulator training before their seagoing service showed that the time to reach the same performance level was 7.25 times shorter using simulator training compared to the time it took during sea time only. The more optimised organisation of the simulator training the more it contributes to a shorter learning time. They conclude that both replacing sea time for simulator time, as well as intensifying the sea time can contribute to a more effective training.

Relevance for this study:

In the context of engine room education, an experimental study demonstrated that the time required for simulator-based training was more than seven times shorter than that needed for equivalent onboard training. The findings demonstrate that competencies can be effectively acquired through simulator-based training.

4.4 Simulator training in the aviation domain

4.4.1 Flight simulator training effectiveness: A meta analysis

Title: Flight simulator training effectiveness: A meta analysis
Authors: T. Hays, J. W. Jacobs, C. Prince and E. Salas
Organisation: US naval training systems center, USA
Year of publication: 1992
Type of literature: journal article covering 247 research articles

Summary:

This meta-analysis of flight simulation research was conducted to identify important characteristics associated with the effectiveness of simulator training and is dated already in 1992. Some 247 articles, research reports, and technical reports were located, from which 26 experiments were identified as having sufficient information for statistical meta-analysis. The major finding was that the use of simulators combined with aircraft training consistently produced improvements in training for jets compared to aircraft training only. Use of motion cuing added little to the training environments for jets. The average effectiveness of performance-paced training was greater than that for lock-step training. In general, training outcomes appear to be influenced considerably by the type of task and the amount and type of training given.

Relevance for this study:

In the aviation domain it was concluded in this study, in 1992 already, that a combination of simulator education and aircraft education improved the quality of the training of future pilots.

Note that the quality of simulation techniques in 2025 is much improved compared to 1992.

4.4.2 Follow-Up Examination of Simulator-Based Training Effectiveness

Title: Follow-Up Examination of Simulator-Based Training Effectiveness
Authors: M. Lubner, A. R. Dattel, D. Henneberry, S. DeVivo
Organisation: Wright State University USA
Year of publication: 2015
Type of literature: conference paper on experimental research

Summary:

It was found that students who followed the intensive, simulator-based flight training programmes earned their FAA Private Pilot certificates in a significantly shorter time than those who attended the conventional flight training programme. Given the small numbers of students tested, this finding of statistical significance indicates that there was a large effect related to the timing of the training effectiveness.

From anecdotal evidence, it appears that the simulator training, close spacing of appointments for flying lessons and psychosocial aspects of camaraderie and intensive learning all contributed to the students' successful, rapid completion of their FAA Private Pilot certificates. Students talked about their social bonding, collaboration on flight training and ability to help each other to reduce anxiety.

Relevance for this study:

In aviation not only type ratings (certificate for a specific aircraft type) are trained in a simulator but also basic training (private pilot certificate). The training time for a private pilot certificate is shorter than pure aircraft based training.

This suggests that a combination of simulator training and seagoing service may be more effective for learning and skill development than relying on seagoing service alone.

4.4.3 Use of Simulation for Pre-Training of Drone Pilots

Title: Use of Simulation for Pre-Training of Drone Pilots
Authors: A. Somerville , T. Lynar , K. Joiner 1 and G. Wild
Organisation: School of Engineering and Technology, UNSW Canberra, Australia
Year of publication: 2024
Type of literature: journal article on experimental research

Summary:

This study investigates the effectiveness of simulator-based training systems in enhancing human drone (or Remote Piloted Aircraft Systems, RPAS) piloting skills and performance. The study utilised a true-experimental research design to assess the impact of simulation training on accuracy, efficiency, and workload perception among human drone pilots.

The study's findings underscore the efficacy of simulator-based training in enhancing the flight performance of drone pilots, demonstrating a clear advantage for those who undergo structured simulation training before engaging in real-world operations. The significant impact of the intervention group's training on their performance, as indicated by the reduced mean relative displacement compared to the control group, validates the integration of advanced simulation technologies in drone pilot training programmes. Contrary to expectations, task loading, did not have a significant impact on flight performance. This research highlights the potential of simulators in improving the skills of RPAS pilots.

Relevance for this study:

Drone operators being trained with a combination of simulator training and real drone operation training experience advantages above the control group of drone pilot being training without a simulator.

This suggests that a combination of simulator training and seagoing service may be more effective for learning and skill development than relying on seagoing service alone.

4.4.4 Literature review on effectiveness, other impacts and safety

Title: Literature review on effectiveness, other impacts and safety (in press)
Authors: J. van der Pal, J. Field, R. Gottwald, A. de Blecourt, E. van Weelen, H. Smit, J. van Rooij, M. Cruellas Bordes, J. Vreeken
Organisation: NLR, Royal National Aerospace Centre The Netherlands
Year of publication: expected 2025
Type literature: report on literature review

Summary:

A transition toward more simulator hours in initial flight training is generally expected to be beneficial in terms of effectiveness and costs, but there is also concern that it may introduce negative effects. To guide decision making towards allowing more simulator time in PPL and CPL the TRAIN project provides empirical results from recent literature and new experiments. This report provides an overview of the available literature on training effectiveness, psychological and physiological impacts, and safety issues related to increased simulator use.

The review found positive transfer effects of simulator training on all training tasks, with strongest effects for take-off, approach and landing. Serious negative transfer effects were not found. There is, however, still limited insight into (the interaction of) specific factors that are found or assumed to determine or influence training effectiveness, such as the type and quality of the simulator, the (type of) task selected, the type of training method applied, the quality of the flight instructor, the type and experience level of student, and how simulator training is blended with actual flying training in the curriculum.

High workload tasks are ideally suitable to be trained first in simulated environments to facilitate effective learning, and then should be complemented by actual flights, allowing students to become accustomed to stress levels in real environments and practise learned strategies to cope with those levels. Moreover, PPL tasks can be adapted in the simulator across multiple domains (auditory, cognitive, visual, and physical), allowing instructors to tailor workload demands to individual student needs.

The findings of the literature reviews highlight both the benefits and limitations of using simulators in pilot training, underscoring the need for a balanced approach that integrates both simulated and real flight experience.

Relevance for this study:

This very broad study on the effectiveness and safety of applying simulator training in initial flight training shows that the combination of simulator training and real flight experience to be optimal. It advises a balanced training approach including simulator and real flight training. These findings support a combination of simulator training and seagoing service is preferable to seagoing service alone.

4.4.5 Certification specification for flight simulation training devices

Title: Certification specification for flight simulation training devices CS-FSTD(A)
Authors: EASA (European Aviation Safety Agency).
Organisation: EASA (European Aviation Safety Agency).
Year of publication: 2018
Type of literature: EU regulation

Summary:

This document describes four levels of flight simulators for training purposes. It makes a distinction between the following types of training simulators: FFS (Full Flight Simulator), FTD (Flight Training Device), FNTP (Flight Navigation Procedure Trainer) and BITD (Basic Instrument Training Device). The Full Flight Simulator concerns the most realistic type of simulator which can be certified on 4 levels. This highest level being level D which can be used to train pilots for a specific aircraft type without flying a single hour in the actual aircraft. The certification specification defines the level of realism the flight simulator should offer in order to be allowed to use is for such a zero flight training. Lower levels of simulator can be applied in a training as well but will require addition flight time training. Here the EU regulation is referred tom very similar regulations can be found from the FAA, Federal Aviation Authority of the USA.

Relevance for this study:

In the aviation domain flight simulators are frequently used for training purposes. In order to make sure the training simulator offers sufficient functionality and is fit for purpose, requirements on the simulator are clearly defined in regulations.

4.5 Simulator training other domains

4.5.1 Exploring the Role of Simulation Training in Improving Surgical Skills Among Residents: A Narrative Review

Title: Exploring the Role of Simulation Training in Improving Surgical Skills Among Residents: A Narrative Review
Authors: Cardoso, S., Suyambu, J., Iqbal, J. et al.
Organisation: University Hospital Birmingham, National Health Service (NHS) Foundation Trust Birmingham, Jonalta School of Medicine, University of Perpetual Help System Dalta, Laspinas City, Mayo Hospital, Lahore and others.
Year of publication: 2023
Type of literature: journal article

Summary:

The role of simulation in medical education is crucial to the development of surgeons' skills. Surgical simulation can be used to improve surgical skills in a secure and risk-free environment. Animal models, simulated patients, virtual reality, and mannequins are some types of surgical simulation. As a result, feedback encourages students to reflect on their strengths and weaknesses, enabling them to focus on improvement. Healthcare simulation is a strong educational instrument, and the main goal of this is to give the students an opportunity to do a practical application of what they have learned through theory. Before taking it to the patients, they will already have certain tools they have previously acquired during the practice. This makes it easier for students to identify the knowledge gaps that they must fill to improve patient outcomes. Moreover, simulation brings a wonderful opportunity for students to acquire skills, gain confidence, and experience success before working with real patients, especially when their clinical exposure is limited.

Simulation training has disrupted surgical education, replacing outdated methods with risk-free, skill-enhancing practice. Shifting from the "look one, do one, teach one" approach, simulation offers a secure environment to learn and execute surgical procedures. Various models, from animals and cadavers to electronic versions, foster experiential learning and align with established theories. Trainees gain technical expertise, decision-making skills, and self-confidence, identifying strengths and areas for growth. Studies affirm simulation's positive impact on participants, minimizing complications and elevating surgical proficiency.

Relevance for this study:

Although the task of a surgeon and a mariner are hardly comparable, simulation is seen as an important improvement of the education of surgeons. Comparable for any domain is that trainees find simulation easier to find their knowledge gaps, identify their strengths and gain technical and non-technical expertise. The advantages of simulator training, such as improving confidence, suggest that a combination of seagoing service and simulator training is an effective learning method.

4.6 Onboard training

4.6.1 An exploration of the theoretical foundations of onboard seafarer training: a systematic review of literature

Title: An exploration of the theoretical foundations of onboard seafarer training: a systematic review of literature
Authors: Y. Mori and M. E. Manuel
Organisation: World Maritime University, Malmö, Sweden
Year of publication: 2023
Type literature: journal article on literature study

Summary:

This article employed a systematic literature review to identify the theoretical foundation of on-the-job training and apprenticeship. The objective was to explore theoretical foundations of apprenticeship/on-the-job training and how they may apply to onboard training in the maritime industry.

The authors conducted an electronic literature search with specified selection criteria for inclusion/exclusion using two databases - EBSCO Discovery Service and SCOPUS. Thereafter, and through qualitative coding of the literature found, several research themes were identified and explored. Using an electronic search with a specific search strategy from the two databases, a total of 3476 studies were identified. After screening per the relevant inclusion and exclusion criteria, 48 studies were ultimately included in the review.

The review of the 48 studies (from a wide range of industries) found no study that focused on the theoretical foundations of onboard training specifically. However, it was confirmed from the study that three macro learning theories – relating to situated learning cognitive apprenticeship [Ref 17.] and the zone of proximal development [Ref 1.] - are the dominant theories that relate to apprenticeship and on-the-job training in general. This review also found that different perspectives relating to processes of learning, guidance and support and the materiality of the context are critical considerations for apprenticeship and on-the-job training.

This work addresses a gap in the literature relating to the theoretical underpinnings of onboard training in the maritime industry and contributes both a theoretical/conceptual framework for onboard training and a theory-informed definition of this expression of apprenticeship. Knowledge about these theoretical underpinnings is essential as the industry considers options for the remission of sea time, the increased automation of ships and the diversity of practices of onboard training in different jurisdictions.

Relevance for this study:

Many industries incorporate on-the-job training as a core component of skill development; in the maritime sector, this is represented by seagoing service. However, unlike other sectors, the maritime industry lacks a clearly defined theoretical framework to support seagoing service as an educational method. This study argues that establishing such a framework is becoming increasingly essential, particularly in light of rising levels of automation and the growing diversity of onboard practices across vessels.

4.7 Conclusion literature study

This chapter covers a number of literature references about learning theories and simulator use in education in the maritime, aviation and surgical domains. In all literature covered in this chapter it is concluded that the use of simulators improves the quality of the education of students and can reduce the training time. No examples are found in which the total training time is increased by adding simulator training, in other words adding simulator training lead to reduction of other part of curricula. For jobs requiring practical skills, such a maritime officers, a combination of simulator education as well as on the job training on board a vessel as seagoing service is in the maritime literature seen as highly recommendable.

Focusing on maritime education, the literature review presented in this chapter supports that simulator training is a valuable and effective complement to seagoing service in maritime education. Evaluated from both a methodological (the 'how' of training) and outcome-based (the 'what' of training) perspective, simulator training aligns closely with the structure, learning experience, and instructional design of onboard training, while offering distinct advantages in terms of safety, control, and accessibility to high-risk scenarios and scenarios seldom encountered during seagoing service.

From a methodological standpoint, simulator environments provide structured, scenario-based learning that mirrors the dynamics of onboard experience but in a more controlled and forgiving setting. This makes simulator training particularly suitable for practicing complex tasks and emergency scenarios that are seldom encountered at sea. It also supports collaborative learning through communities of practice, where students and instructors engage in shared reflection and feedback.

From an outcome-based perspective, simulator training contributes significantly to competence development. It enhances skill acquisition, builds learner confidence, and fosters positive work related attitudes and behaviours. Studies consistently show that simulator training can reduce the time required to reach proficiency without compromising educational quality. Moreover, it prepares students for their seagoing service, increasing the educational value and enabling more effective learning during real-world operations.

Evidence from other high-risk job domains such as aviation and surgical training further reinforces the effectiveness of simulation-based education. In aviation, for example, simulators are used extensively for both basic and advanced training, supported by clear regulatory standards for fidelity and functionality. These practices highlight the importance of integrating simulation into maritime education, especially as onboard systems become more automated and diverse.

5 MARITIME ACADEMIES, STUDENTS AND STUDY COORDINATORS

5.1 Introduction and method description

In the initial phase of this research contacts were established with the maritime academies. Literature related to onboard training and simulator training was gathered and the general topics of seagoing service and simulator usage in education were discussed with study coordinators. The literature review as described in chapter 4 indicates a widely application of simulators in education and training for high-risk jobs. It shows that in several domains simulators are used as an effective training environment which bridges theoretical learning and practical skill acquisition. Maritime academies in the Netherlands incorporate simulators to a varying degree in their educational programme. Given both statements – simulators used as an effective training environment and the Netherlands using simulators in maritime education– it is hypothesised that evaluating the latter will show clear argumentation for the use of simulator training as an equivalence for seagoing service.

Therefore, in the second phase of this research the various maritime academies were visited, and study coordinators, seagoing service coordinators, and students were interviewed. Interviews were conducted in a part structured way, and in a part qualitative way. Students were interviewed with a questionnaire based on the STCW Convention regarding shipboard training as a general framework. Questions were mostly open-ended, and structured according organisational factors, substantive factors, and goal-related factors of a seagoing service or simulator training.

Organisational and substantive factors relate to the evaluation of the ‘how’ of seagoing service and simulator training, focusing on aspects such as training method, structure, and learning experience. Goal-related factors, on the other hand, pertain to the evaluation of the ‘what’, the outcomes and overall effectiveness of simulator training in combination with seagoing service. The literature review identifies scenario-based training as an effective complement to seagoing service, particularly for emergency and complex scenarios. It also highlights several elements that enhance overall learning outcomes, such as increased self-confidence and better preparedness among students. The interviews and questionnaires are expected to substantiate these findings and to provide additional insights.

Due to the timing of this project, the maritime academies were visited between April and June 2025, most of the interviewed students were in their third year of study. Fourth-year students were largely unavailable, as they were engaged in their second seagoing service. Consequently, the majority of respondents could only provide insights into their first seagoing experience and mostly MSTC modules 1 and 2.

The primary objective of these interviews was to gather students' perspectives on both their seagoing service and simulator training. The findings from these experiences provides argumentation for the importance, relevance, and benefits of integrating simulator training within the seagoing service period.

In total 60 students were interviewed:

Table 5-1: Participants

Total			N/A
	Medium Vocational Level Students	Higher Vocational Level Students	
60	43	17	
	Navigational Officer Students	Engineering officer Students	
60	42	12	6

5.2 Mentorship and support in student development and students' initiative

5.2.1 Seagoing service

Introduction

When students were asked about how they perceived their induction upon boarding their vessel, most reported a positive experience. This was primarily related to the often mentioned familiarisation tour and/or a safety briefing. However, students were less satisfied with the clarity of objectives and expectations for their seagoing service onboard the vessel. Many stated that they had to define these themselves where self-initiative was of prime importance. Some had particularly negative experiences, feeling left to navigate everything on their own without proper guidance.

For example one student states: *"No, I didn't receive a proper introduction. On the bridge, I was completely left to fend for myself. They didn't know what to do with an intern"*; while another student states: *"This was well organised. Upon arrival onboard, you first had to complete all administrative tasks with the required forms. You received a safety briefing and a familiarization tour from a student who had been on board longer. Additionally, you were given a task list for the first few weeks."*

Table 5-2: Introduction onboard the vessel (n = 60)

60 STUDENTS:	
Introduction perceived as good	30
Introduction perceived as moderate	19
Introduction perceived as poor/less effective	11

Mentorship

When students were asked about their experiences with onboard mentorship in general, their responses varied. Some reported positive mentorships during their seagoing service, receiving guidance from both an engineering officer and a bridge officer for their respective tasks and duties. Some mentioned having one assigned mentor or training officer, (which in all cases was perceived as good), while others noted differences in the quality of mentorship received in the bridge and engine room.

The quality of mentorship appeared to depend largely on the motivation of the assigned mentor. Some students initially had poor guidance, which later improved following a crew or company change. Others stated that no one took on the sole role of a mentor during their time onboard. Additionally, some students experienced challenges due to language barriers, which made effective guidance more difficult.

One student recalls: *"There wasn't necessarily one person assigned as a mentor, so it depended on who was willing to take on that role. Fortunately, there were a few people who did"*, and another student: *"No mentor was assigned, and there was little time for reports because the crew had no idea how much schoolwork needed to be done"*, while other experiences were more positive: *"On board the ship, there was a training officer specifically assigned to support the interns. The training officer helped approve the internship reports and monitored the progress of the task books"*.

When students were asked whether they received mentorship from their academy, the company, and/or aboard the vessel, their responses varied. Most reported receiving guidance both from their academy and onboard. Some experienced mentorships solely onboard the vessel, while others received support only from their academy. Additionally, some students mentioned having a designated contact person within the company whom they could reach out to.

From the students interviews it becomes apparent that the level of mentorship varies a lot. Some students indicate that they were mentored in a structured manner and could perform relevant tasks onboard. Other indicate that they were left with lower rank officers who did not permit the student to actually perform tasks themselves.

In the following table it is shown who were involved with the student during his internship onboard.

Table 5-3: Mentorship roles (n = 59)

	59 STUDENTS:
Mentions only the internship supervisor on the ship	14
Mentions only the internship supervisor from academy	6
Mentions both the ship and academy	23
Mentions both the ship and the company	6
Mentions both the academy and the company	0
Mentions the academy, the company, and the ship	10

Role expectations regarding seagoing service

The Training Record Book is intended to be an instrument that shapes and guides the expectations and learning possibilities of a student. To summarise: time on board needs to be planned and structured to enable prospective officers to acquire and practice skills and offer opportunities for competences achieved to be demonstrated and assessed. The Convention requires that a students' seagoing service therefore must be recorded in a Training Record Book.

Students were asked if their time on board was planned and structured. Most students responded by given their assigned shifts on board, for example from 08:00 – 17:00. Only a couple of students remarked that they were free to plan and structure their own time. However, how duties and tasks were assigned during work time varied. Most students had the possibility to work on their Training Record Book during watchkeeping shifts. Often the Training Record Book was mentioned as something that needed to be completed as a part of schoolwork students need to do on board. Some students mention that they were only allowed to work on schoolwork outside working hours. Other students mention dedicated time for schoolwork: *"Fortunately, I was given plenty of time for my schoolwork, the first 6 hours of the day were dedicated to schoolwork, then 6 hours of watchkeeping."*

Students were asked how they worked on their Training Record Book. Students were asked if they made a planning and worked dedicated to complete their tasks. Answers varied in general in students who planned their tasks, often in consultation with their mentor, and in students who looked after their tasks in retrospective. Both are represented in the following quotes: *"I followed the task book in a structured manner and completed everything well ahead of time"* and *"I don't believe in having a fixed plan; I think you should engage with the actual work on board, allowing the task book to be completed naturally as a result."*

For completing tasks, the way in which students received guidance varied. Some mention enthusiastic crew who offered learning opportunities and input, while others mention they are redirected to shipboard documentation and manuals to study for themselves. Onboard, the Training Record Book is generally seen as the sole responsibility of the student. To get tasks initialled, students mostly had to arrange a moment themselves: *"In my case, the officers and engineers were authorised to sign off on tasks. However, I often had to be quite persistent in asking them to review my task book"*.

When asked how watchkeeping duties were arranged, most students indicated that they had at least 4 hours of watchkeeping duties under a responsible officer a day. How this time was used varied. Some answered that this time was mostly used reading manuals, or to rest, with almost no responsibilities.

Others mention that during their seagoing service they received gradually more responsibilities in tasks and duties.

Individual motivation and self-initiative

One recurring theme emerging during discussion of the questions is the importance of reported self-initiative and motivation by the students for making most out of their time onboard. In receiving guidance, responsibilities, and in working and completion the Training Record Book, students had to show initiative. In some cases, students compared themselves with other students onboard, who showed less self-initiative. They mentioned crew was less willing to help, and these students had a less effective time onboard. To succeed in both seagoing services perceived as structured and with good mentorship, and seagoing services perceived as less structured and with less mentorship, self-initiative was key.

5.2.2 Simulator Training

Introduction and mentorship (MSTC)

Most students mention a good introduction during the simulation week, wherefrom several report an introduction with a duration of 3 days. For students it was clear what to do, and when. Some groups received an introduction at their own academy.

All students were (very) positive about the guidance they received in the simulator training weeks, and the practical experience of the instructors is found helpful. Students mention the well-structured and clearly organised lessons and the professional attitude towards students. Guidance was primary delivered by the varying simulation-instructors for each session. During the dedicated simulation weeks at Terschelling organisational guidance was given by a dedicated person. Sometimes a teacher from a maritime academy joined the students however, had no active role.

A simulation session consisted of a briefing (50 minutes) a simulation (50 minutes), and a debriefing (50 minutes). Each day consisted of several sessions, either in the bridge simulator or the engine room simulator. Some students felt they were thrown in the deep end during the sessions however, received help and instructions when needed.

Role expectations regarding simulation training (MSTC)

Module descriptions for the MSTC simulation weeks can be found in Appendix 1. In these documents the contents of the diverse simulation sessions are brought in relation with the STCW Convention. In the scenario-descriptions the learning outcomes for the students can be found.

During discussions with the students however, although the introduction was perceived as good, they did not recall communicated learning outcomes or objectives for the simulation weeks, apart from an objective from a certain scenario during a simulation session. When asked how the students worked on their objectives, they said they followed the schedule and rotated each simulation session. Only during the debriefing, it became clear what needed to be done better, which was taken to the next session. When asked if students were graded, or if tasks were initialled, students reported that only feedback was given during the debriefings.

Individual motivation and self-initiative (MSTC)

In general, students followed the schedule for the simulation weeks and had no input to steer towards specific learning outcomes. One student recalls: *“A strict schedule was followed, with no opportunities for developments outside of that schedule or for taking self-initiative”*.

5.3 Competence development in (ab)normal situations

After completing seagoing service students are expected to have achieved an overall standard of competence. This implies that future officers are able to work at different ships and across a range of circumstances, and are able to anticipate, prepare for and deal with contingencies.

Students were asked to which degree they received watchkeeping related experience in different conditions. These conditions differed in conditions related to weather, traffic, area limitations and to conditions where certain ship or machinery handling is necessary. Second, students were asked if they felt they gained more watchkeeping experience during seagoing service or during simulation training in these varying circumstances.

Table 5-4 shows the results to which degree students felt they gained experience in the following conditions which can be expected during seagoing service:

Table 5-4: *Experience in (ab)normal situations during seagoing service*

Conditions	Experience in ↓ / gained →	None	Limited	Moderate	Substantial	n =
Weather	Fair weather	0	2	29	28	59
	Adverse weather	3	16	32	8	59
	Night conditions	2	8	26	23	59
	Restricted visibility	7	24	23	3	57
Traffic	Ocean crossing	24	4	14	17	59
	Uncongested waters	1	9	30	19	59
	Congested waters	1	18	30	10	59
Area	Confined waterways	2	28	20	9	59
	Shallow waters	7	31	12	8	58
Special	Manual steering	7	22	17	13	59
	Anchoring	9	13	28	9	59
	Port approach / berthing	3	12	21	23	59
	Emergency situation	21	25	10	3	59

It can be concluded that not every student felt they gained experience in every circumstance. For example, several students did not conduct an ocean passage or never gained experience when sailing in restricted visibility. Discussions with the students revealed that the experience acquired during their seagoing service was primarily based on exposure to the various situations, especially the more challenging ones, rather than on the performance of specific duties typical for their future role in those situations.

Most students never encountered or had only limited experience with emergency situations (78%). Students who reported substantial experience in emergency situations (n = 3), all recalled incidents onboard cruise vessels where passengers required medical treatment. After spending a minimum of 5 months onboard a vessel, (almost) half of the students reported limited to no experience in shallow waters (66%), restricted visibility (54%), congested waters (32%), anchoring (37%), confined waterways (51%) and manual steering (49%). Discussions with the students revealed that this was largely dependent on the specific trade and operational area of the vessel.

Next, students were asked to compare seagoing service and simulator training in terms of the level of experience each provided. The results indicate that certain circumstances were more effectively addressed through simulator training. Almost all students reported gaining more experience in handling emergency situations during simulator sessions.

Table 5-5: Experience at sea or in a simulator

Condi-tions	Experience in ↓ / gained →	Only at sea	More at sea > sim	More in sim > sea	Only in sim	No	n =
Weather	Fair weather	8	35	8	2	3	56
	Adverse weather	18	25	9	2	2	56
	Night conditions	8	38	8	0	2	56
	Restricted visibility	5	20	23	4	4	56
Traffic	Ocean crossing	31	8	2	1	14	56
	Uncongested waters	9	30	11	3	3	56
	Congested waters	4	27	22	2	1	56
Area	Confined waterways	9	29	15	2	1	56
	Shallow waters	6	20	22	5	3	56
Special	Manual steering	6	20	21	8	1	56
	Anchoring	37	12	5	2	0	56
	Port approach and berthing	10	32	9	2	2	55
	Emergency situation	6	8	17	20	5	56

A relationship is suggested when the percentage of reported 'none to limited' experience at sea is compared with the reported experience in scenarios where the simulator was considered more beneficial. This is illustrated in Figure 5-1. Most situations wherein students reported a higher degree of 'none to limited' experience received at sea, showed a higher degree of experience gained during simulator training.

It must be noted that there is a significant time difference between the amount of seagoing service and simulator training. In this case, the students reflect on an average 150 days of seagoing service and 10 days of dedicated simulator training (MSTC modules 1 & 2). The many instants a simulator is pointed out as the tool which was more beneficial for gaining experience, show therefore the effectiveness of simulator training. The results show that dedicated training of a certain scenario in a simulator translates to a higher amount of perceived experience gained than exposure to that scenario at sea. This can be explained: simulator training asks active participation of a student in handling a certain situation.

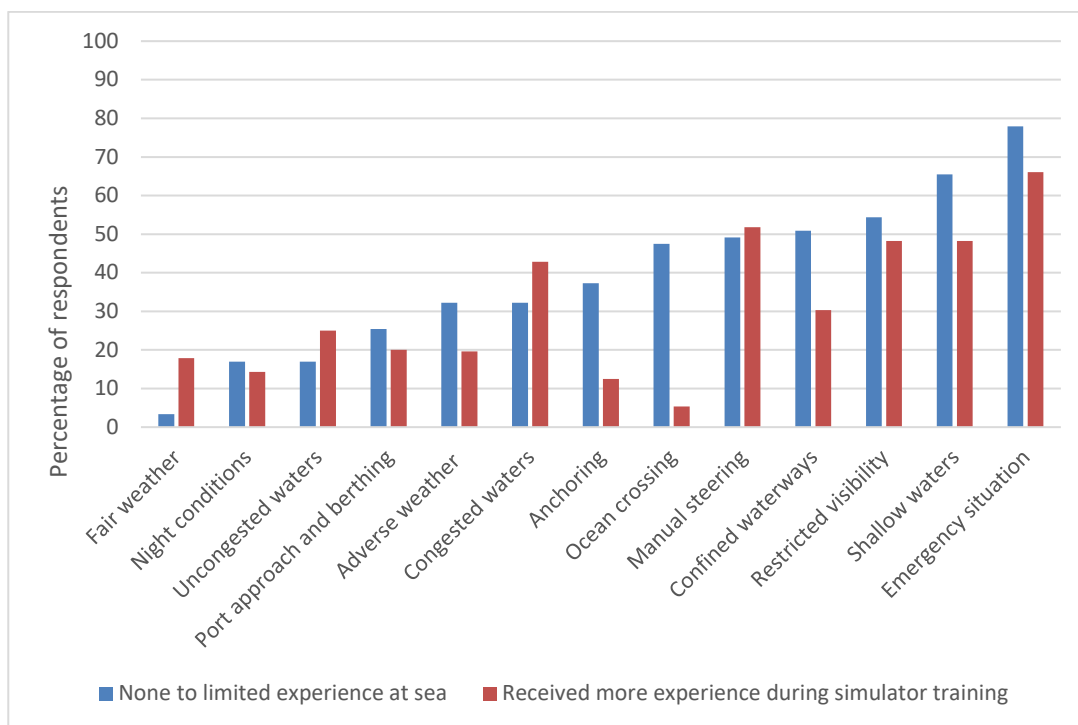


Figure 5-1: Relationship between 'none to limited'-experience in a scenario and experience in a simulator for that scenario

In Table 5-6, the scenarios used in the MSTC bridge simulator are linked to various operational conditions. This helps explain the differing levels of experience reported with anchoring and ocean crossings. Although anchoring is included in the scenarios, closer inspection reveals that it primarily involves the approach to an anchorage. The full anchoring process, such as lowering the anchor and chain, is not simulated. Additionally, the scenarios tend to focus on more challenging conditions, allowing students to apply different aspects of their knowledge depending on the specific situation.

Table 5-6: Scenarios MSTC

Conditions		Scenarios MSTC
Weather	Fair weather	
	Adverse weather	
	Night conditions	<i>Hinder Junction; Foxtrot 3; Crossing Dover Strait</i>
	Restricted visibility	<i>Boulogne departure</i>
Traffic	Ocean crossing	
	Uncongested waters	
	Congested waters	<i>IJmuiden approach; Crossing Dover Strait; Dover Strait SW-Bound; Foxtrot 3; German bight</i>
Area	Confined waterways	<i>Harwich Out; Great Belt; San Francisco Bay;</i>
	Shallow waters	<i>Princes Channel; East of St. John's; San Francisco Bay</i>
Special	Manual steering	(almost all scenarios involve manual steering)
	Anchoring	<i>Anchoring at Denver</i>
	Port approach and berthing	<i>Zeebrugge Arrival; IJmuiden approach; Rotterdam in</i>
	Emergency situation	(often scenarios end up in an emergency situation)

5.4 Practical implications of seagoing service and simulator training

5.4.1 Seagoing service

Maritime education in the Netherlands

STCW requires 12 months of seagoing service but since the Netherlands has issued the equivalency principle the maritime academies in the Netherlands offer 10 months of seagoing service often split into two periods of each 5 months. The first seagoing period, in the first half of the third educational year, students aboard vessels for both engine room and bridge operational level competencies. The second and last seagoing service, students have chosen to finish their education at management level in either engine room or bridge competencies.

During the visits, the topic of internships and simulator training was broadly discussed with study and internship coordinators. These discussions are summarised and given in blue text boxes.

Internship Coordinator Point of View

Firstly, the coordinators general finding is that the quality of a future officer depends on the quality of the internship. The coordinators mention there is little oversight in this regard. When asked if measures are taken in case of a low quality internship environment, the coordinators mention action for replacement to another vessel is only taken when complaints arise from the shipping company or from the intern. In the end, is mentioned, there is no clarity about the quality assurance of an internship, or who is responsible for it: the academy, the shipping company, or the ship.

It is emphasised by the coordinators that a student's personal motivation and attitude are important for the quality of the internship. However, it is noted that this can be stifled onboard due to working conditions or the crew. A large difference in the quality of internship logbooks is observed by the coordinators. More detailed descriptions are often a sign of an healthy internship.

Coordinators see, despite these varying circumstances, that almost everyone returns from their internship with a completed task book. The 300 days are considered more than sufficient to complete all the assignments in the task book. The academy however, has the final say in the assessment of the task books. If signatures appear to have been collected suspiciously, students may be required to make up for this during their second internship.

During the discussions it becomes clear students receive internship orientation before they leave for their seagoing service. This introduction mainly covers norms and values, emphasises the learning attitude, and aims to make students more worldly. There seems no specific guidance on how a student can get the most out of their internship, what they are minimally entitled to expect on their internship ship, and how they can assert those rights.

Furthermore, the coordinators stress there is no insight into the quality of the mentors on board or how students are involved in the onboard processes.

5.4.2 Simulator training

Simulator Training at the Maritime Academies

Maritime academies were visited to interview students and teachers. All academies in the Netherlands follow roughly the same education schedule in which at least 40 hours of simulator education is given at each individual academy (i.e. module 1). Most academies however use the simulator far more than this minimum of 40 hours. Next, all academies send their students to the MSTC (Maritiem Simulatie en Trainingscentrum), a dedicated simulation education centre at Terschelling, for 80 hours of simulator education. In addition to this minimum of 3 weeks simulator education all academies apply two times five months seagoing service.

Each maritime academy in the Netherlands is required to have at least 40 hours of simulator education offered by the academy itself (as part of the modules in how the equivalent arrangement currently is implemented). The maritime academies, however, have offered and integrated simulator training in their education programmes where simulation training by far exceeds this required 40 hours.

Since all visited academies offer a basis of at least 3 weeks simulator education and twice five months of seagoing service the responses of all students, teachers and other stakeholders can be compared.

An example of actual simulation hours (given solely for navigation) offered by an academy (during 4 years), by far exceeding the norm of 40 hours set forward by module 1:

Table 5-7: *Navigation simulator maritime academy (1)*

Simulator	Hours
Navigation Simulator Desktop	48
Navigation Simulator Full Mission	131
Navigation ECDIS	38
Navigation RADAR	19
Navigation BRM	18
Total	254

In total, depending on the specialisation, a student receives at the maritime academy Table 5-8 in the first 2 years of education 108 hours of simulation training (bridge specialisation), or 88 hours of simulation training.

Table 5-8: *Hours of additional simulator training in a maritime academy (2)*

Year	Time	Learning goals
Year 1 – Dual	42 hours bridge simulations	Bridge equipment familiarisation, usage of radar equipment
	21 hours engine room simulations	Engine room simulator familiarisation, start cold ship, fault diagnostics
Year 2 – Bridge officer	45 hours bridge simulations	Bridge equipment (radar, ECDIS, GMDSS) usage, manoeuvring (in different scenarios), MCRM (Maritime Crew Resource Management), preparing MSTC
Year 2 – Engine room officer	25 hours simulations	High Voltage, Refrigeration Systems, Fuel Systems, Auxiliary Systems
Year 3 – Bridge officer	26 hours simulations	Scenario based training, MCRM
Year 3 – Engine room officer	15 hours simulations	Fault finding, ERM (Engine Room Management)
Year 4 – Bridge officer (MINOR)	20 hours simulations	Scenario based training, manoeuvring, MCRM

The topics concerning simulator education vary. Mostly, at the academies, the simulator is used for introduction and familiarisation and competence-based training in both engineering and navigation. The fidelity of the simulators range from low to high fidelity. Some teachers argued that practicing with real machinery is a form of high-fidelity simulation. For bridge simulation a quite common setup is found at all academies, being a bridge working position including the main instruments and controls. For engine room education environments, a broader range of education environments is found. Some academies

use engine room simulators but, in some cases, real pieces of equipment are used as part task training devices. For example, a complete functioning engine as part task trainer is used. Table 5-9 shows one can debate whether this a highly realistic simulator or not. Bottom line is that such real equipment setup is used in the education of students in a controlled environment with a teacher in close connection with the students. This serves the same goal as bridge simulators: a teacher who teaches student how to handle specific, pre-defined, controlled scenarios in a safe environment of the academy.

Table 5-9: Working equipment and general performance standards for simulators

STCW General performance standards for simulators used in training (Part A-I/12)	Working diesel engine in maritime academy
Be suitable for the selected objectives and training tasks	When the training task is to perform the starting procedure of a diesel engine, a real diesel engine is suitable
Be capable of simulating the operating capabilities of shipboard equipment concerned, to a level of physical realism appropriate to training objectives, and include the capabilities, limitations and possible errors of such equipment	A working diesel engine provides high physical realism appropriate to for example in training the starting procedure of a diesel engine
Provide a controlled operating environment, capable of producing a variety of conditions, which may include emergency, hazardous or unusual situations relevant to the training objectives	A working diesel engine in a classical, open set up provides a controlled operating environment, capable of producing a variety of conditions. However, for practical and safety reasons, hazardous and emergency situations are avoided.
Provide an interface through which a trainee can interact with the equipment, the simulated environment and, as appropriate, the instructor	The diesel engine situated in the operating room, including a supervising or guiding instructor, is the interface to which a student can interact.
Permit an instructor to control, monitor and record exercises for the effective debriefing of trainees	An exercise, as for example the starting procedure of a diesel engine with a working diesel engine, can be controlled, monitored, and recorded by an instructor for the effective debriefing of trainees.



Figure 5-2: *Firda Urk, working machinery as part task training device*

Competency-based training is either directed at engineering or navigation skills. For engineering competencies, a maritime academy listed the following to be learned in the simulator:

1. Describe the operation and safety systems of the engine using various systems in the simulator;
2. Explain the start and stop procedures of a steam boiler;
3. Engage and disengage auxiliary engines according to proper procedures;
4. Engage and disengage auxiliary equipment according to proper procedures;
5. Determine, based on operational values, whether the load limits of an engine in operation are not exceeded;
6. Explain, using indicator diagrams, the factors that influence the efficiency of a diesel engine;
7. Identify the normal operating conditions of the fuel injection system;
8. Set and maintain different system parameters at the correct values;
9. Analyse the proper functioning of a steam system and its individual components while it is in operation;
10. Correctly start and stop the water maker and explain what to consider during the production of drinking water;
11. Start up, shut down, and troubleshoot a thermal oil system properly;
12. Properly switch generators in parallel, manually and automatically, disconnect them, and explain how the main switchboard is protected and regulated;
13. Describe the automatic operation of the steam boiler;
14. Explain, using the simulator, the different ways a pump in a piping system can be automatically started and stopped;
15. Explain how the proper functioning of various pump systems is checked.



Figure 5-3: Engine Room Simulator; Rotterdam



Figure 5-4: Engine technical workshop room; Rotterdam

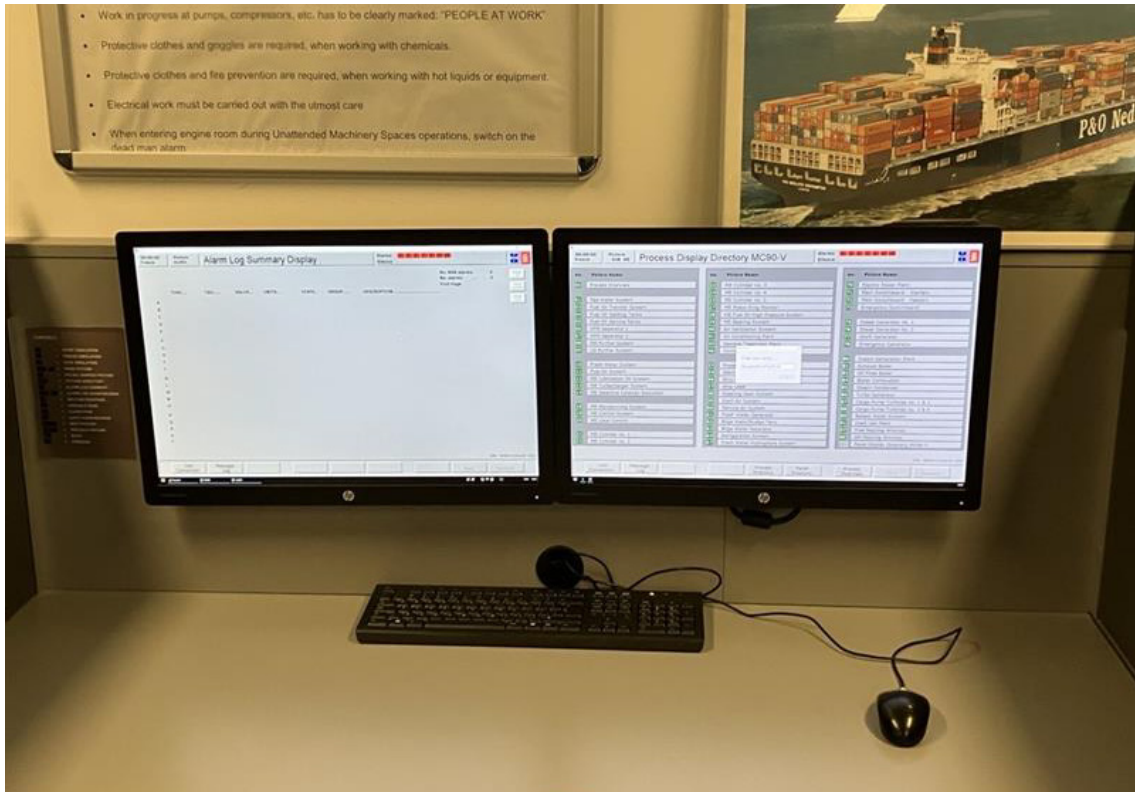


Figure 5-5: Individual engine room work station; Rotterdam

This academy describes the following structure for simulator-training:

- Lessons have duration of 3x45 or 2x45 minutes.
- Covering various scenarios and ship models.
- Depth in subject matter (for engineering) where ship model allows.
- Structure: briefing, exercise of 50 minutes, debriefing.

Another academy offers, next to simulator lessons adjacent or integrated in regular education weeks, a dedicated simulator programme consisting of several days. The academy stresses their students to have learned the relevant theory before starting such a week. Table 5-10 gives an example of how these days are structured.

Table 5-10: Part of a course as used in a maritime academy, translated from course documents

Part 4		
12:45	00:30	THEORY: voyage planning, ETA, logbook entries, positioning in ECDIS (visual)
13:15	00:30	BRIEFING EXERCISE 4: making voyage planning and ETA for Copenhagen
14:15	14:30	coffee break
14:30	01:30	EXERCISE 4: making voyage planning and ETA for Copenhagen
16:00	00:30	DEBRIEFING
16:30	00:15	assign homework
Part 5		
08:45	00:30	discuss homework
09:15	00:30	THEORY: familiarisation, course wrap up, communication, route planning, current planning
09:45	00:30	BRIEFING EXERCISE
10:15	00:15	coffee break
10:30	01:00	EXERCISE 5: Sydney
11:30	00:15	DEBRIEFING
11:45	12:00	course conclusion and evaluation form

Especially at academies offering medium vocational level structured assessment of competencies is seen in the simulator. For example, students are assessed at management level navigation in the simulator. Figure 5-6 shows tasks related to table A-II of the STCW Convention.

	0	1	2
W1: Navigation at the management level	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Rationale			
Manoeuvring the ship			
Operates (or has operated) the rudder as necessary			
Operates (or has operated) bow and stern thrusters (if present).			
Takes into account the manoeuvring characteristics of the ship.			
Communicates internally (with the crew) in the correct manner.			
Adjusts course and speed depending on the planned route and the shipping traffic in the immediate vicinity.			
Takes into account wind and current			
Anticipates the inertia of the ship, squat, and interaction with other vessels when passing.			
(empty space for comments or notes)			

Figure 5-6: Assessment form – with translated parts by MARIN



Figure 5-7: Practicing between theory and simulator

Study instructor Point of View

In a conversation with an instructor at a maritime academy it becomes clear in what ways the simulator is nowadays rooted in the educational system. The instructor explains how the academy at medium vocational education level 4, implements module 1 of MSTC in maritime education. He explains how this is done through two sessions of two and a half days of focused simulator training. A setup meeting the MSTC requirements according to the instructor.

The instructor explains how this is done: during these simulator days, efforts are made to maximise simulator time, a topic which is still being fine-tuned. It is stressed by the instructor that time is not used to re-explain theory. If a day is missed, it must be made up later. The simulator days have their own theory/course booklet.

First-year students receive their first module 1 course after six months, lasting two and a half days. The goal is for students to learn to look outside and navigate by sight. The simulator is hereby used as an introduction to seafaring according to the instructor. Simulations follow the pattern: briefing / simulation / debriefing.

Regarding simulator training within the regular curriculum, it was further stated: "The further along in the programme, the more valuable it becomes."

In the second year, students take the second two-and-a-half-day module 1 simulator course. Here, the focus shifts more toward using radar and other equipment; the simulator is not solely used as an introduction and familiarisation tool, but also as a competency training tool.

The instructor explains that at this academy, the simulator is also used for the Proeve van Bekwaamheid (PvB), or Proof of Competence. At the end of the second year, students are examined on the simulator at the Operational Level. These are intensive days: 3.5 days of practice, half a day of voyage planning, and one day of sailing. Students sail the exams in groups, but they are assessed individually, the instructor explains.

At the end of the fourth year, a PvB is conducted at the Management Level. This is intensive and individual, with a strong focus on BRM (Bridge Resource Management).

To sum up, the instructor explained that at this academy students receive simulator training in three different ways: part of the regular curriculum (competence development); module 1, as equivalent arrangement (with focus on familiarisation, introduction) and PvB (competence assessment). Simulation training is thus used for familiarisation/introduction, competence-based training, and BRM/communication training, and the simulator is used for assessment.

During the visits, study instructors expressed the importance of visualizing and doing, and that tools such as shown in Figure 5-9 guided students to better results.

5.5 Optimum onboard training

5.5.1 Seagoing Service

In the following questions, students were asked how many months they needed to get competent in different ship related topics. These topics are derived from the STCW-guidance for the shipboard programme of training and are also considered in the Training Record Book.

Table 5-11: Perceived time needed to become competent (n = 60)

Months	avg	1	2	3	4	5	6	7	8	9	10	no exp.
General seamanship	2.5	20	12	16	4	2	2	2	1			1
Steering systems	2.6	17	15	10	11	2		1	2			2
Mooring	2.5	19	12	13	5	1	2	1	2	1		4
Anchoring	2.7	14	14	11	7	3	2	2	1	1		5
Port Operations	3.0	9	19	11	8	6	2	1			2	2
Life-saving/fire-fighting equip.	3.1	16	13	12	4	4	3	4	1		2	1
Systems and equipment	3.2	11	13	13	11	3	5		3			1
Cargo work	2.9	14	9	11	5	4	4	2	1		2	8
Bridge work/Watchkeeping	3.1	12	13	16	6	4	5	1	1		1	1
Engine room familiarisation	2.9	17	16	11	4	4	2	2	1	1	1	1
<i>Total participants</i>		60										

Table 5-11 shows that most students experienced to be competent in a work area after 2.5 to 3 months. Some students stressed that when they filled in a longer period, it meant that the relevant tasks and duties regarding a working area didn't occur in the first months. However, most topics were mastered in parallel.

When asked why students did not fill in a month by a certain topic, they answered that their ship didn't offer the opportunity to learn tasks and duties regarding that topic. For cargo work, the most answered reason was that their vessel was a cruise vessel. In general, when the learning opportunity for a certain work-topic is available, students experience to become competent in about 2.5 - 3 months. Students were asked if they felt they were competent for their future role as officer onboard a vessel after their seagoing service, and when that was the case, or they thought when that would be the case, after how many months of seagoing service they thought to have received that competency. The results are given in Table 5-12:

Table 5-12: Felt competent for their future role as officer

Months	1	2	3	4	5	6	7	8	9	10	not competent / no estimate
Average = 5.4	0	1	5	10	15	4	2	1	0	6	16
<i>Total participants</i>	60										

Related to this question, students were asked after how many months, or after how many months they expected to have exhausted all the learning opportunities offered during their seagoing service, not necessarily implying they were competent. This resulted in the following table:

Table 5-13: Exhausted learning opportunities for improving further

Months	1	2	3	4	5	6	7	8	9	10	not exhausted
Average = 5.2	1	4	0	8	10	5	1	0	0	5	26
<i>Total participants</i>	60										

Students were asked in what fields they felt they lacked knowledge or experience, when they felt they were still incompetent after the seagoing service:

Table 5-14: Areas lacking knowledge or experience

Areas lacking competence	n = 31
Work regarding engine room	13
Stability	2
Cargo Work	15
Mooring	7
General Seamanship	4
Regulations	1
Ballasting	1
Lifesaving Equipment	5
Watchkeeping	9
Steering Systems	5
Systems and Equipment	6
Anchoring	7
Port Operations	6
Manoeuvring	1

Lastly, students were asked to reflect on the equivalent arrangement and seagoing service. Most students found, or expected 10 months as a reasonable amount of seagoing experience.

Table 5-15: How many months seagoing service?

Months	1	2	3	4	5	6	7	8	9	10	11	12
Average = 9.9	0	0	0	0	0	2	1	7	3	34	5	8
Total participants	60											

Half of the students reported to be competent for their future role as officers after 5.4 months of seagoing service. A quarter of the students could not estimate, based on 5 months of experience, when they would be competent for their future role. These results suggest that the first seagoing service period (5 months) was a period of high learning in the relevant tasks and duties of a bridge or engine-room watchkeeping officer.

It must be noted that expectations of being competent mostly reflect the tasks and duties of the relevant officers on the particular vessel during the first seagoing service. Students who felt they were not yet competent and couldn't give an estimation mostly reflected on this limitation.

Table 5-15, which asked students how many months of seagoing service they believed were necessary, shows a broader reflection of the overall standard of competence and the subsequent needed seagoing service.

In summary, the results suggest that per competence field about 3 months are needed to become competent. Because most fields are developed in parallel, though not always, the sum of competence fields results in 5.4 months, mostly because of the limitations of receiving experience on only one vessel. Without these limitations considered, the expected overall standard of competence is reached after an average of 10 months seagoing service. This seems to indicate that students expect to have acquired

after 10 months the relevant positive work attitudes and behaviours needed to handle different vessels and situations, not necessarily having experienced those vessels or situations.

Area's lacking knowledge or experience, as shown in Table 5-14, mostly reflect on the learning opportunities available during the first seagoing service of 5 months. To a lesser extent it reflects on the time needed to become competent for a certain task (as shown in Table 5-11). These tables offer insight in how simulator training, (or other training methods), can complement seagoing service, aside from the clear advantage of scenario-based simulator training in Table 5-5 for emergency and more demanding situations.

5.5.2 Simulator Training

Students were asked to describe their experience with simulator training as an alternative for seagoing service. Students listed the following advantages and disadvantages, which could be grouped in different aspects of a seagoing service:

Table 5-16: *Opinions about simulator training as an alternative for a part of seagoing service*

Concept	Quote positive	Quote negative
Preparation for seagoing service/ Added value	"A solid foundation for my internship." "You get a bit of preparation so you can get started more easily during your internship." "Combination with internship works well." "Preparation for working with different brands of equipment (radar, ECDIS)." "At sea, you can't try things out or let them go wrong."	"One week is not enough to become competent." "The simulator cannot be compared to the internship." "I barely learned anything." "Not without internship." "Simulator alone is not sufficient."
Emergency situations	"Simulator prepares you for emergency/unusual situations." "Black-out exercise, gyro error, GPS error." "Crisis management and responsibility in difficult conditions."	
(Ab)normal scenarios	"Many different scenarios in a short time." "Situations like shallow water and closed waterways due to collisions."	"Everything happens in a fixed order, while on board it's different."
Communication	"Practicing communication on the bridge." "Working in a large team with different roles."	"BRM nonsense, it wasn't applied on board because we only had one person on the bridge."

For seagoing service, the following concepts were listed as having special added value for going to sea:

Table 5-17: *Added value for going to sea*

Concept	Quote
Social aspects	"Social skills, dealing with colleagues (different cultures and languages)." "Teamwork, conditions like broken main engines, social skills and cultures on board." "Mooring and dealing with the crew."
Safety and drills	"Emergency situations and safety on board." "Drills and social skills."

Concept	Quote
	"How it really works, you learn to set priorities."
Life at sea	"You only really learn what life at sea is like once you're there. It's realism. It's a big ship." "How things go on board and how everything runs." "The real hands-on experience." "Seasickness."
Practical experience	"Working on deck and cargo handling." "Manoeuvring the ship and more communication with other vessels." "Most of the tasks that had to be performed, including ice navigation and social skills."

Ultimately, the students were asked for their opinion of the equivalent arrangement as it is today, and if there is room for more simulator education instead of seagoing service. The answers are given in table 5-18, in general agreeing with the current practice, or opting for increasing simulator time, thereby referring to be able to train different scenarios, getting the responsibility or being able to make mistakes:

Table 5-18: *Examples of opinions about the equivalent arrangement*

Opinion	Quote
Positive (more simulator time)	"It's a good addition. You practice reflection. You're allowed to make mistakes, you learn to deal with problems. You're put on the spot." "Certainly, in my case bridge work was monotonous (ocean crossing). Moreover, various situations can occur at the MSTC, which is very valuable." "It aligns well, and three weeks in the simulator is actually better, since you might be inactive for two months as well." "I think one week at the MSTC is more valuable than a month on board." "I believe that after spending a certain amount of time onboard a ship, you've reached the learning ceiling for that internship. To reach a higher level, it's necessary to dive back into the books and sit in the lecture halls. You can then apply that new knowledge during your second internship."
Neutral (current arrangement good as it is)	"No, I definitely wouldn't shorten the internships. In the end, the internship is the real world, and a simulator is merely an approximation of that reality. I also think that the two weeks on Terschelling are sufficient." "The current arrangement is good. An extra 60 days at sea would just be more of the same. MSTC is different. More simulation-based education should replace time at academy rather than time at sea. So the way it is now works well. It would be great if you could plan your internship more flexibly: a different distribution of the 10 months."
Negative (prefer seagoing service)	"I believe that you learn more during an internship." "Three weeks is too short to compensate for two months of internship." "No. Although you can gain similar knowledge in both places, there will never be a better way to learn than through real-life practice."

In all discussions with students, an influencing factor of their general attitude was their experience (positive or negative) of the learning environment and learning opportunities onboard the vessel. Also, some students expressed a high enthusiasm for just working on the vessel, being in the work environment, even when the time onboard and the job tasks did not necessarily guide them to their future roll as officer.

6 DISCUSSION

Study objectives

The objective of this study was to assess the effectiveness of the equivalent arrangement (EA) in terms of simulator training as replacement for a part of the seagoing service as defined in the current STCW Convention.

Main findings

The main findings in this study are that simulators offer a very valuable educational environment which can effectively be applied to develop competences for navigational officers and marine engineering officers. The basis for this finding is the performed literature survey and the observation and interviews at 10 maritime institutes. Apart from the use of simulators in the curriculum, seagoing service remains an essential part of the education for a seafarer to learn the way of life onboard and to experience applying competences in real world conditions. The added value of simulator education justifies a reduction in seagoing service time, in order to create space in the curriculum for simulator training. A seagoing service reduction from 12 to 10 months and adding 15 days of simulator education as applied in the Netherlands provides a high quality education for seafarers.

Specific competences can be learned more effective in simulators.

Specific competences can be learned more effective at simulators than on board a vessel. In a simulator specific situations can be created and repeatedly trained which is not an option onboard a vessel. A simulator offers a student the opportunity to perform tasks him/herself in complex conditions which is not possible on board a vessel since the risks would be too high. Experience in handling in certain scenarios, like emergency situations, is found to be gained better in a simulator. The simulator seems to be a solution to complement a seagoing service in offering competency in conditions seldom encountered at sea.

The results of interviewing students show that important scenarios were limited trained, or not at all trained, during seagoing service. Most students never received, or had limited experience with emergency situations (78%). Students who reported substantial experience in emergency situations (n = 3), all recalled situations onboard cruise vessels where customers needed medical treatment. After a minimum of 5 months onboard a vessel, almost half of the students reported limited to none experience in shallow waters (66%), restricted visibility (54%), congested waters (32%), anchoring (37%), confined waterways (51%) and manual steering (49%). During discussions with students it became apparent that this was largely dependent on the specific trade and working area of the vessel. (More details in Table 5-4).

Next students were asked to compare seagoing service and simulator training in relation to the level of experience it provided. Students indicate that the simulator scenarios focussed often on challenging conditions and scenarios. It is worth noting that students in a simulator are actively in control of the situation even in the challenging scenarios. In contrast, onboard during the seagoing service the students were often only observer in challenging scenarios due to the real life risks. From an educational perspective being actively involved in a scenario results in a higher training effect than being an observer.

The latter is also supported by the literature covered in chapter 4, see amongst others [Ref 3.], [Ref 4.], [Ref 5.] and [Ref 10.] for research which underlines the effectiveness of simulator education. Main benefits found are the advantage of training emergencies and other rare situations in a controlled environment with instructors to manage the learning process of the student.

The combination of seagoing service and simulator education is key

This study focusses on the combination of seagoing services and simulator education and by no means to rely solely on simulator training. It is the combination of both training methods which serve as an effective training as a whole. Experiencing the real life on board remains an essential part of the curriculum. [Ref 14.] gives a very clear statement about this combination. It states that high workload tasks are ideally suitable to be trained first in simulated environments to facilitate effective learning, and then should be complemented by actual, real life situations, allowing students to become accustomed to stress levels in real environments and practise learned strategies to cope with those levels. In other words, the simulator education creates a basis of competencies which allows students to act in onboard situations with a baseline of confidence. While being put in a high workload or stress situation onboard without this competence basis, the training value is far less because of not being able to handle the high workload or stress situation. This is also supported by [Ref 3.] in the sense that in high workload situations the support for the student should be high in order to be able to acquire competencies. In high workload situations however the focus onboard is on a safe operation rather than an effective training of the student, as it is explicitly stated in the STCW.

Table 5-6 shows for a number of relevant scenarios and situations for a navigation officer in how many cases the seagoing service and the simulator training added to the training of the student. The added value of having the combination of both seagoing service and simulator training is apparent.

Apart from both, the seagoing service and the simulator education, having their own added value to the learning process of a student, some maritime institutes use the simulator as preparation for the seagoing service. Having a better prepared student stepping onboard a vessel to start his seagoing service makes the seagoing service more effective. The benefit which the institutes experience is that a student can start onboard immediately when having had this preparation. While without it, more time is lost in the initial phase of the seagoing service. It adds to the possibility to reduce seagoing service time, although being a limited reduction and difficult to quantify.

Less than 12 months seagoing service adding simulator education

A part of the basis of this study was observations and interviews at 10 maritime institutes. All of these institutes make use of the equivalent arrangement as defined in STCW.2/circ7 and STCW.2/circ55 as described in Sections 3.2.1 and 3.2.2 in this report. These define, in brief, an equivalency of 10 months seagoing service and 15 days of simulator education to the STCW defined 12 month seagoing service. All interviews and observations are made within the framework of this specific combination of seagoing service and simulator education. Over a period of 30 years this has been the standard for all civil seafarers being educated in the Netherlands. During this period of 30 years students receive their certificate, and shipping companies are eager to hire these new seafarers as crew members on their vessels.

Reducing the seagoing service to less than 10 months while adding more simulator education is seen as a viable option. The data shows that students estimate being competent well before 10 months of seagoing service. Table 5-11 presents the estimated time per competence to become competent being less than 3 months. However, becoming competent is not just acquiring a set of single competences but covers the complete task of an officer. So, upon the question after how many month the students would be competent or exhausted their learning capabilities, more than halve answers about 5-6 months. The proof whether such a reduction is really feasible cannot be concluded based on this study though. Less than 10% indicate to need 10 months. Relevant in this sense is to look at Table 5-5 which presents the contribution to the learning process of both simulator education and seagoing service. This table shows that even with only 15 days of simulator education, the scores are high compared to the much longer period of seagoing service to experience various conditions. Increasing the simulator education time and further reducing seagoing service time will increase the potential for competence development in various conditions This applies very clearly for emergency situations but also reduced visibility, shallow waters and congested waters to name the most obvious ones.

Limitations of the study

The question whether a seagoing service of less than 10 months would be feasible is not easily answered and not in detail investigated in this study. Table 5-11 shows that students perceive being competent for individual competences far before having completed their 10 months of seagoing service. Table 5-12 and Table 5-13 show that students indicate being competent clearly less than 10 months. However, asked directly what they seem required for seagoing service period, the majority opts for a period of 10 months. Still a further reduction of seagoing service and increase of simulator education is seen as viable. However, based on this study no quantifiable duration of seagoing service can be defined.

Not covered in this study but for future exploration relevant are some expected changes in the maritime domain. On both the bridge and the engine room more and more automation is in development. This will result in a larger variety of bridge layouts and equipment and ultimately in a change of tasks to be performed by the navigational officers. Support from ashore will be part of these developments which will have its impact on the navigational officer tasks to be performed. On the vessel propulsion side various developments can be seen in the market. Wind assist propulsion, hydrogen, ammonia and even nuclear energy sources might be introduced sooner or later. With a larger variety of tasks to be performed (either on the bridge or engine room), simulator education can offer a wider range of vessel characteristics than two times a seagoing service can offer. This is far beyond the scope of this study but is worthwhile to mention at least as a factor of relevance for defining future regulations for seaman competencies.

Implications of the study

The study focusses on the equivalency principle and concludes that a combination of seagoing service and simulator education is a very effective way of educating future seafarers. The equivalency of 15 days simulator education and 10 months of seagoing service to 12 month seagoing service without simulator education has proven to be effective. It is therefore recommended to offer maritime institutes the possibility to tailor their curriculum within certain boundaries. A baseline of a minimum of 12 months seagoing service without any requirement for simulator education can remain. The possibility of offering a curriculum containing 10 months of seagoing service and 15 days of simulator education should be covered as well. A further reduction of seagoing service time and increase of simulator education time seems viable but will require a clear proof that the resulting curriculum leads to students acquiring the required competences as defined in the STCW Convention. Exact numbers for minimum duration of seagoing service and simulator education cannot be given based on the study at hand.

7 CONCLUSIONS AND RECOMMENDATIONS

The objective of this study was to assess the effectiveness of the equivalency principle in terms of simulator training as replacement for a part of the seagoing service as defined in the current STCW Convention. The goal is to use the outcome of this study as clear argumentation for the use of simulator training in the process of the comprehensive review of the STCW Convention and have the equivalency principle being part of the renewed STCW Convention.

The conclusions drawn in this chapter are based on a literature review, both within the maritime training context as well as training contexts of other domains. Next, 10 maritime institutes were visited for observations and interviews.

7.1 Conclusions

Literature and experiences from maritime institutes underline that simulators offer a very valuable educational environment which can be effectively applied to develop competences for navigational officers and marine engineering officers.

Using, high fidelity simulators in the education of maritime officers offers the opportunity to master relevant competencies and knowledge. It supports the understanding and becoming proficient through a structured approach training and evaluating competences in a controlled learning environment. For creating time in a curriculum in order to increase the amount of simulator education it is achievable to reduce seagoing service time since the combination of both simulator education and seagoing service is more effective than seagoing service only. More specific, it can be stated that a reduction from 12 to 10 months seagoing service and adding 15 days of simulator training results in an effective, high quality, curriculum.

Simulator education should always be considered in combination with seagoing service, which remains an essential part of the education of a seafarer, both for navigational officers as well as marine engineering officers, to learn the way of life onboard and to experience applying competences in real world conditions.

Simulator education is by far the most effective way to educate subjects rarely encountered at sea, whereas sea going service hardly offers the opportunity to learn how to act in such rare operational situations.

In addition, simulator technology allows for a more standardised assessing process of students.

Increasing the amount of simulator education time and reducing the amount of seagoing service time to less than 10 months seems viable but requires a more in depth study to define the exact minimal durations of both seagoing service and simulator education.

7.2 Recommendations

In order to allow maritime institutes to create an effective curriculum based on nowadays insights in educational science and making use of state of the art educational tooling, the STCW should ideally provide room for optimisations within boundaries. Using approved simulators for training can help future officers learn the skills they need for safe navigation or engineering watch more quickly, reducing the time they need to spend at sea. The current requirement of 12 months seagoing service might be rephrased by a well-defined bandwidth of possible combinations of seagoing service and simulator education. A baseline of a minimum of 12 months seagoing service without any requirement for simulator education can remain. The possibility of offering a curriculum containing 10 months of seagoing service and 15 days of simulator education should be covered at least. A further reduction of seagoing service and increase of simulator education time might be feasible to acquire the required level of competences as defined in the STCW. Exact numbers for minimum duration of seagoing service and simulator education cannot be given based on the study at hand.

The developments in the maritime industry are ongoing and with respect to higher level of automation, remote assistance from ashore, new propulsion systems using new energy sources might require more attention in the education of officers. Simulation might be an essential solution and the effectiveness of seagoing service on two or at least a limited number of vessels might not be sufficient anymore. In the process of reviewing the STCW this topic might require further elaboration.

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APPENDIX

APPENDIX 1 MSTC DOCUMENTS

MSTC description of modules

Module 1:

STCW correlation

Knowledge of the following themes and, typically (but not limited to) operational level, STCW-competences:

		A-II/1	A-II/2
Bridge simulator	<ul style="list-style-type: none"> Voyage preparation Use of nautical charts and publications 	102	115
	<ul style="list-style-type: none"> Execution of the voyage plan Terrestrial and coastal navigation 	102	115
	<ul style="list-style-type: none"> Ship maneuvering and handling 	109	119
	<ul style="list-style-type: none"> International Regulations for Preventing Collisions at Sea 	105	116
	<ul style="list-style-type: none"> The interrelationship and optimum use of navigation data 		117
	<ul style="list-style-type: none"> Operating principles of marine power plants 		117
	<ul style="list-style-type: none"> Equipment usage Electronic systems of position fixing 		120
	<ul style="list-style-type: none"> Echo sounders 	102	
	<ul style="list-style-type: none"> Compasses 	102	
	<ul style="list-style-type: none"> Steering control system 	103	116
	<ul style="list-style-type: none"> Radar navigation 	103	
	<ul style="list-style-type: none"> Navigation using ECDIS 	103	
	<ul style="list-style-type: none"> Appreciation of system errors 	105-106	117
	<ul style="list-style-type: none"> Communication IMO Standard Marine Communication Phrases 	107	(117)
		<ul style="list-style-type: none"> Usage of the international code of signals 	117
		108	
		109	
Engine room simulator	<ul style="list-style-type: none"> Maintenance and repair Safety measures Drawings and handbooks Troubleshooting Watchkeeping Watchkeeping principles Operation of automation and control systems Safety, security and protection of environment Equipment operation Main engine Generators Boilers Propulsions systems Steering gear Auxiliary systems Communication IMO Standard Marine Communication Phrases Internal communication systems 		
Cargo simulator	<ul style="list-style-type: none"> Differences between ship types Effects of cargo on ship stability Basics of safe and efficient cargo (such as oil and chemical) transfers Ballast systems and procedures 		

Module 2:

Understanding and application of the following themes and, typically (but not limited to) operational level, STCW-competences:

Module 3:

Integration of the following themes and, typically (but not limited to) operational level, STCW-competences:

STCW correlation

		A-II/1	A-II/2
Bridge simulator	<ul style="list-style-type: none"> • Voyage preparation Use of nautical charts and publications 	102	115
	<ul style="list-style-type: none"> • Execution of the voyage plan Terrestrial and coastal navigation 	102	115
	<ul style="list-style-type: none"> • Execution of the voyage plan Ship maneuvering and handling 	109	119
	<ul style="list-style-type: none"> • Execution of the voyage plan International Regulations for Preventing Collisions at Sea 	105	116
	<ul style="list-style-type: none"> • Execution of the voyage plan The interrelationship and optimum use of navigation data 		117
	<ul style="list-style-type: none"> • Execution of the voyage plan Operating principles of marine power plants 		120
	<ul style="list-style-type: none"> • Bridge Resource Management Allocation, assignment, and prioritization of resources 		120
	<ul style="list-style-type: none"> • Bridge Resource Management Effective communication 	104	
	<ul style="list-style-type: none"> • Bridge Resource Management Assertiveness and leadership 	104	
	<ul style="list-style-type: none"> • Bridge Resource Management Obtaining and maintaining situational awareness 	104	
	<ul style="list-style-type: none"> • Equipment usage Electronic systems of position fixing 	104	
	<ul style="list-style-type: none"> • Equipment usage Echo sounders 		
	<ul style="list-style-type: none"> • Equipment usage Compasses 	102	
	<ul style="list-style-type: none"> • Equipment usage Steering control system 	102	
	<ul style="list-style-type: none"> • Equipment usage Radar navigation 	103	116
	<ul style="list-style-type: none"> • Equipment usage Navigation using ECDIS 	103	
	<ul style="list-style-type: none"> • Equipment usage Appreciation of system errors 	105-106	117
<ul style="list-style-type: none"> • Communication IMO Standard Marine Communication Phrases 	107	(117)	
<ul style="list-style-type: none"> • Communication Usage of the international code of signals 	117		
<ul style="list-style-type: none"> • Emergency procedures Respond to navigational emergencies 	108		
<ul style="list-style-type: none"> • Emergency procedures Initial actions following accidents or incidents 	109		
<ul style="list-style-type: none"> • Emergency procedures Search and Rescue (IAMSAR) 		118	
		108	
		108	116
Engine room simulator	<ul style="list-style-type: none"> • Maintenance and repair Safety measures 		
	<ul style="list-style-type: none"> • Maintenance and repair Drawings and handbooks 		
	<ul style="list-style-type: none"> • Maintenance and repair Troubleshooting 		
	<ul style="list-style-type: none"> • Watchkeeping Watchkeeping principles 		
	<ul style="list-style-type: none"> • Watchkeeping Operation of automation and control systems 		
	<ul style="list-style-type: none"> • Watchkeeping Safety, security and protection of environment 		
	<ul style="list-style-type: none"> • Engine-room Resource Management Allocation, assignment, and prioritization of resources 		
	<ul style="list-style-type: none"> • Engine-room Resource Management Effective communication 		
	<ul style="list-style-type: none"> • Engine-room Resource Management Assertiveness and leadership 		
	<ul style="list-style-type: none"> • Engine-room Resource Management Obtaining and maintaining situational awareness 		
	<ul style="list-style-type: none"> • Equipment operation Main engine 		
	<ul style="list-style-type: none"> • Equipment operation Generators 		
	<ul style="list-style-type: none"> • Equipment operation Boilers 		
	<ul style="list-style-type: none"> • Equipment operation Propulsions systems 		
	<ul style="list-style-type: none"> • Equipment operation Steering gear 		
	<ul style="list-style-type: none"> • Equipment operation Auxiliary systems 		
	<ul style="list-style-type: none"> • Communication IMO Standard Marine Communication Phrases 		
<ul style="list-style-type: none"> • Communication Internal communication systems 			
<ul style="list-style-type: none"> • Emergency procedures Maintain seaworthiness of the ship 			
Cargo simulator	<ul style="list-style-type: none"> • Ship-type (tanker) specific cargo operations 		
	<ul style="list-style-type: none"> • Cargo planning principles 		
	<ul style="list-style-type: none"> • Ship stability and strength 		
	<ul style="list-style-type: none"> • Ballasting procedures 		
	<ul style="list-style-type: none"> • Handling cargo 		

Scenarios Module 2 – Navigation Bridge

Exercise	Objective	Learning Outcomes	Prerequisites	Briefing	Student action	Instructor Action	Debriefing
Goteborg departure	To familiarize the students for the first time with the 360 bridge, it's equipment and MSTC procedures.	To become familiar with the bridge and find out the necessity of the different roles: Head of Watch, Navigator, Co-Navigator and Assistant Watch Officer.	Basic theoretical navigational knowledge. Completed Module 1.	The student team is to prepare for the voyage autonomously. Questions can be asked to the simulation facilitator/instructor, who checks in at regular intervals.	Take initiative in briefing, perform team-briefing. Monitor own ships' track. Keeping a proper lookout and acquire targets. Determine risk of collision and act according to COLREGs. Plan ahead and decide when and where to change course. Listen to VHF communications and messages. Take initiative in debriefing.	Monitor and observe students and ascertain if objectives are met. Monitor conversations in relation to SMCP. Deal with all targets according to COLREGs or otherwise for learning purposes.	Ask the students what went well and what can be done better. Student initiative in this discussion is to be encouraged. Students need to be assured that they are in a 'safe' environment in which feedback can and should be given to each other. Start a discussion by means of peer review. Point out positive actions. This exercise should create an urge to ask questions about the use of radar.
Hinder Junction	The students are expected to plan and conduct a night passage through busy waters in a TSS and act according ColRegs.	Head of Watch: Allocation, assignment, and prioritization of resources; Assertiveness and leadership; Obtaining and maintaining situational awareness; Radar navigation					
IJmuiden approach	Follow the TSS towards IJmuiden. Direct immersion into the exercise in somewhat complicated but self-resolving traffic situation. 1st challenge: turn to starboard in TSS whilst taking into account an overtaking vessel on SB side. 2nd challenge: cross a field of sailing yachts participating in a regatta. Complicating factor: rainclouds cluttering the radar. This exercise is designed to create learning moments with regards to the setting up and using of radar.	Navigator: Ship manoeuvring and handling: International Regulations for Preventing Collisions at Sea; Operating principles of marine power plants; Radar navigation					
Anchoring at Dover	Navigate in the ITZ from the SW going lane to an anchor position SW of Dover Port. Communication with VTS in Dover Strait, Dover Port control and if applicable with vessels nearby. Communication on board with ER, crew and other departments.	Co-Navigator: Effective communication; IMO Standard Marine Communication Phrases; Usage of the International Code of Signals; Radar navigation					
Princes Channel	Calculate window of passing shallow water bank princess channel and Shivering sand.						
Foxtrot 3	Night exercise: Plan ahead of situations, overtaking, crossing and when to change course. Lookout and proper use of radars and ECDIS.	Assistant Watch Officer: Terrestrial and coastal navigation; The interrelationship and optimum use of all navigational data; Navigation using ECDIS; Appreciation of system errors.					
East of St. John's	Prepare and monitor a route using basic navigational skills of visual bearings, radar navigation (PI) and radar target plotting, passing shallow rocks in a coastal passage in approaching and entering a Port.						
South China Sea to Singapore	Prepare and monitor a route using basic navigational skills of visual bearings, radar navigation and radar target plotting entering a TSS.						
Full Mission Helsingor - Helsingborg	Communication and cooperation between the bridge team and engine room team.						

Scenarios Module 3 – Navigation Bridge

Exercise	Objective	Learning Outcomes	Prerequisites	Briefing	Student action	Instructor Action	Debriefing
Fam Dungeness	To (re-)familiarize the students with the 360° bridge, it's equipment and MSTC procedures.	To become familiar with the bridge and find out the necessity of the different roles: Head of Watch, Navigator, Co-Navigator and Assistant Watch Officer.	Basic theoretical navigational knowledge. Completed Module 1.	The student team is to prepare for the voyage autonomously. Questions can be asked to the simulation facilitator/instructor, who checks in at regular intervals.	Take initiative in briefing, perform team-briefing. Monitor own ships' track. Keeping a proper lookout and acquire targets. Determine risk of collision and act according to COLREGs. Plan ahead and decide when and where to change course. Listen to VHF communications and messages. Take initiative in debriefing.	Monitor and observe students and ascertain if objectives are met. Monitor conversations in relation to SMCP. Deal with all targets according to COLREGs or otherwise for learning purposes.	Ask the students what went well and what can be done better. Student initiative in this discussion is to be encouraged. Students need to be assured that they are in a 'safe' environment in which feedback can and should be given to each other. Start a discussion by means of peer review. Point out positive actions. This exercise should create an urge to ask questions about the use of radar.
Boulogne departure	To construct a turn into the NE-bound traffic lane, keeping a sharp lookout, use of ARPA in poor visibility and maintain safe speed/navigation in poor visibility.	Head of Watch: Allocation, assignment, and prioritization of resources; Assertiveness and leadership; Obtaining and maintaining situational awareness; Radar navigation					
Crossing Dover Strait	This exercise trains the student with the anticipation of the dangers at crossing Traffic Separation Schemes (TSS Junction), sailing under night conditions and watch responsibility.	Navigator:					
Harwich Out	Preparation and execution of a voyage plan from port to port (Harwich to Rotterdam) maneuvering in port while proceeding to sea via Sunk East TSS, applying BRM techniques using SMCP.	Ship manoeuvring and handling: International Regulations for Preventing Collisions at Sea; Operating principles of marine power plants; Radar navigation					
Great Belt	Follow route Tango. Line up in TSS to pass under the bridge. Accommodate for traffic. Use all available means to monitor the voyage.	Co-Navigator: Effective communication; IMO Standard Marine Communication Phrases; Usage of the International Code of Signals; Radar navigation					
Rotterdam in	This exercise trains the student with BRM team interaction, closed loop communication, to have situational awareness, maneuvering whilst approaching and entering a port (Use vessel maneuver characteristics).						
Dover Strait SW-bound	Plan ahead/making proper decisions with regards to complex traffic situations.						
German Bight	Plan ahead of situations, whether to overtake or not, crossing a lane and when to change course. Lookout and proper use of radars.						
San Francisco Bay	Depart from Richmond in a safe, efficient and controlled manner. The vessel will be in a shallow and narrow fairway and there will be opposing traffic which might cause ship to ship interference, bank suction or rejection and immersion caused by squat. During the majority of this exercise manual steering is required.	Assistant Watch Officer: Terrestrial and coastal navigation; The interrelationship and optimum use of all navigational data; Navigation using ECDIS; Appreciation of system errors.					
Full-Mission Zeebrugge Arrival	The ship's officers are to bring the ship safely into the port of Zeebrugge. The team needs to assertively exercise control over the ship. Timing is of the essence here. All bridge equipment is to be utilized to have a good situational awareness.						

MARIN
P.O. Box 28

6700 AA Wageningen
The Netherlands

T +31 317 49 39 11
E info@marin.nl

I www.marin.nl
   