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The role of green technology in education of Marine Engineers

An exploratory research in what the maritime industry in Norway assumes the marine engineer need to learn from the academia the next decades.

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This thesis is worth 30 credits study points

1 Abstract

The maritime industry is a dynamic, international, and competitive industry with multiples actors. It is also an industry with both national and international regulations and laws, as shipping is a global activity.
To stay competitive in the maritime industry it is of importance to think strategy, be innovative, follow regulation and s laws, and be willing to take risks.
Like a shipowner, the academia must “steam forward” to be relevant for the maritime industry to produce marine engineers with the right, green technology competence to operate the fleet the next decades.
The world is in change and the UN’s goals for 2030 and 2050 demand new, green technology with environmental-friendly solutions for shipping, and this requires competence by the people operating these ships.
I have done an exploratory research in a selection of the Norwegian maritime industry to find out what *they* assume and expect by the marine engineer with bachelor’s degree the next decades.
The interviewers have stated their answers based on *their own* knowledge, experience, and assumptions to operate low- and zero-emission ships.
To sustain competitive as an education centre, academia must be innovative and flexible in the way they teach their students, and a reframing of the study plan is suggested.
A continuous evaluating together with the students and the maritime industry on the study plan can contribute to make the academia relevant in many hence.
My research has shown that the maritime industry expects rapid changes in ship operations the next decades and in a much faster way than the laws and regulations can follow.
And therefore, it is relevant for the marine engineer to possess competence to approach new, green technology in the education.

Key words: *green technology, marine engineer, education, hydrogen, zero-emission, maritime industry*

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2 Acknowledgements

From the time I began to make a draft around this topic and to the thesis proposal was approved several changes happened in a shortly time perspective, and I had to re-draft several times before my finally problem and research questions were settled. I found out that topics related to environmentally solutions were enormous and I had a hard time to limit my thesis instead.

I have meet nothing but helpful understanding and help wherever I have turned my questions, and I realize that this is a topic that engages many.

I will thank my supervisor Per Haavardtun at USN for support during my writing, my Manager Jarle Myrbø for facilitation at work and constructive reflections, my good friend Kåre Pettersen for continues feedback and, of course all my interviewers for positive, interesting, and helpful interviews.

I will also thank my two sons, Mathias and Andreas for being patients and understanding for having a more or less permanent office in the living room for a longer time. This will now be removed!

Tønsberg, November 21st 2021

Tormod Nordeng

3 Introduction

3.1 Theory and background

This thesis has two main reasons to be written, one is the historical perspective (the past), and one is the future. These two reasons were taking in consider when I choose to write this thesis and are relevant to refer to during the interviews and research.
It is in some way a similar situation when ships went from sail to steam as we today are going through the green shift – *what will the future bring and how shall we relate to the future?*
Further I will discuss the results using theories based on *Lotte Darsø; Innovationspædagogik – Kunsten at fremelske innovationskompetence (2011)* and themes from the course PED5501 at USN (2020) which contains among others *Vygotski, Sellberg* and *Wiik.*

3.1.1 Innovation pedagogy

A theoretical framework called "The Diamond of Innovation" by Lotte Darsø (2003) is based on how new concepts will be handled in group, and with what opportunities and challenges this can make. Darsø define innovation competence as the ability to navigate efficiency with others in complex contexts (2013).
The model has four dimensions, all of which should be in play if the innovation process is to be successful. They are concepts, relations, knowledge, and ignorance. The four dimensions should be exploited to the fullest through dynamic interaction. The perpendicular axis represents communication and putting things into perspective. The poles of the axis of knowledge and ignorance are not the opposites of each other.
Darsø has developed four management roles to support the four dimensions: the innovation gardener, the innovation jester, the innovation conceptualizer, and the innovation challenger.
Further define Darsø project and preject (Darsø, 2011, p. 67) as something specified to achieve within specified frames in a process (project) and seeking process (preject) to identify barriers before a project.
The purpose is to identify a new concept or a strategy question thru innovative crystallization.

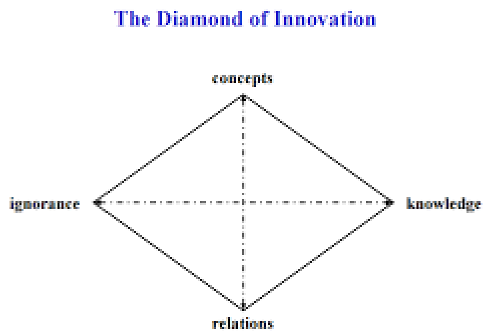

Figure 1 The Diamond of Innovation

3.1.2 Vygotsky's view on pedagogy and education

Lev Vygotsky (1896-1934), in some hence called The Mozart of Pedagogy, is a physiologist with a great influence on pedagogy and learning effects through language and social interaction. Some of his learning themes are (but by far not reduced to):

- *Youth and children's right to develop their own personality and creative potential in schooling*
- *Changes in the teacher role turning away from teacher led instructions towards a supervisor role and scaffolding students in close collaboration*
- *Use students everyday experience and knowledge as resources for learning*
- *Underline's student's agency and need for learning activities*
- *Methods must be adapted to students needs*

3.2 From sail to steam

Characteristics of the 1800's was global growth in ships tonnage and volume, and during the same time it was an emergence of technical innovations in the industry.

The steam engine was invented and slowly found its way from trains and pumpstations on shore to be propulsion engines on ships. The world's first boat with steam as propulsion was *Clermont* in 1807, built and sailed on Hudson river in USA.

In Norway *DS Constitutionen* was the first steamship and it came in 1826, and from now on it become more possible to keep routes within time schedules regardless weather- and wind conditions.

The first routes in Norway were in south-east of Norway to transport mail and passengers operated by the Government.
The steam technology was expensive to operate and high-cost ships and the routes along the coast was the first decades largely subsidized by the Government.
Later the Government supported the shipowners with large amounts of financial supports to build infrastructure supporting operations of steamships.
It was not costly comparable to ship cargo in bulk or larger amount with this new technology, and the Norwegian shipowners were non-risk to invest capital in building steamships, but instead bought sail ships abroad from countries who turned to the new technology and build steamships also for bulk.
As most other innovations steam was non-economic success in the beginning but through development and innovation it become cost effective thru the years.
In Norway several ship owners went bankrupt in the late 1800's since they did not notice a change in the market of new technology and ended up ordering big tonnages of sail ships. They could not compare on time and reliability with their sail ships versus steam ships and went out of business.

3.3 The Marine Engineer

When going from sail to steam, it was no education system for what later became *Marine Engineers,* but it became clearly as the ship became larger in size, more technically complex, the technical innovation developed rapidly and more rotary engines that needed maintenance by qualified personnel.
The Royal Norwegian Navy started the first marine technical education in Norway for their personnel on warships in the mid 1800's, and commercial education began in the beginning of 1900's.
Since the shipping went from sail to steam the Marine Engineer must now operate, maintain, and diagnose all power systems on board based on fossil combustion.
Therefore, today's study plan for Marine Engineer at Bachler Degree includes a great amount of theory and practises related to fossil combustion.
Through my thesis I want to make research if the maritime industry has expectations to the Marine Engineer to be more environmental focused when graduated.

Without possibility to refer to any statically or research many of Norwegian Marine Engineers with license will work in near coast fleet, at some time in their career. Ferries, fast boats and aqua are in a very green period due to governmental adjustments and economical schemes. It is in this maritime segment green technology have come the furthest in Norway.
Norwegian Marine Engineers in near coast fleet are, and will be, exposed for new and green technology with fast changing both in re-build and new building of ships and there will be changes in the regulations of national tenders for sea going transportation in Norway in 2024 and 2025.

> *Shipping accounts for 2.2% of global greenhouse gas emissions. Norwegian shipping companies will now take the lead and take the in the fight against the climate challenges. By 2050, the goal is for the entire Norwegian fleet to be climate neutral.* (Norges rederiforbund, 2021).

With this statement it seems the Marine Engineers will have jobs, opportunities, possibilities for influence a major role in maritime industry for many decades to come!
From Norwegian Maritime Authority (A, Aamundstad-Balle, personal communication, November 2021) I have received information related to number of valid M1 licences (highest grade) and age groups.
The information in table 1 gives an overview over valid M1 issued by NMA and age groups, but it doesn't tell us if they are active on sea, working in positions with requirement of possession to M1 or if it is in near-coast fleet or world-wide fleet.
This table of information must be seen in hence of the reform on 5-year turnover for renewal of STCW licenses implemented in 2016 (renewal cycle is 5 year from 2016).
The information gives an indication on when to expect apostasies of licenced marine engineers with M1 and which age groups that will be sailing the next decades.

Number of valid M1 certificates	Age group
14	77-81 years
43	72-76 years
115	67-71 years
268	62-66 years
370	57-61 years
443	52-56 years
528	47-51 years
418	42-46 years
432	37-41 years
428	32-36 years
374	27-31 years
56	20-26 years

Table 1 Number of valid M1 certificates and age groups. Made by author.

3.4 International Maritime Organization (IMO)

The International Convention on Standards of Training, Certification and Watchkeeping for seafarers (STCW) 1978, as amended, sets the standards of competence of seafarers internationally. The STCW Convention is implemented in national laws and laws by ratifications.

The 1995 STCW Conference adopted the Seafarer's Training, Certification and Watchkeeping (STCW) Code.

The STCW Code contain part A (mandatory, minimum standard) and B (recommended guidance). In order to assist with uniform interpretation, IMO has developed a series of model courses (IMO Model Courses) with suggested detailed teaching syllabus and learning objectives in hence to assist instructors develop training programs to meet the STCW Convention.

Norway, as a member of United Nations and IMO has ratified STCW Convention and have few, national supplements, or deviations. In addition to this Norway is committed to European Maritime Safety Agency (EMSA).
Maritime institutes providing international (and individually national) training and education, like the academia, must relate to these commitments which are revised by NMA and Nasjonalt organ for kvalitet i utdanningen (NOKUT).
This means the academia must follow the minimum requirements, but have the possibility to interpret STCW Code, IMO Model Courses and Norwegian regulations to fulfill the study plan in accordance with STCW Convention.

3.5 The United Nations Sustainable Development Agenda

The Sustainable Development Goals (SDG) are a collection of 17 global goals set by the United Nations. Each goal has a separate list of targets to achieve, and achieving all 169 targets, the 17 SDGs will be met. The SDGs cover social and economic development issues including poverty, hunger, health, education, climate change, gender equality, water, sanitation, energy, urbanization, environment, and social justice. The SDG are a global call of action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity.
Climate change is accelerating, become more intense and some of the trends are now irreversible according to the latest report released August 2021 from the UN Climate Panel.
In shipping there are two significant years in this hence: 2030 and 2050.
The International Maritime Organization's (IMO) initial strategy on greenhouse gases (GHGs) is challenging system integrators, shipping companies, and owners to find, develop and integrate new and more energy-efficient solutions, to meet GHG emissions reduction targets for 2030 and 2050.
Supporting the United Nations Sustainable Development Agenda, the IMO's initial GHG strategy aims to reduce carbon emissions by 40% by 2030 (IMO 2030) from 2008's levels and cut at least 50% of the shipping industry's total greenhouse gas emissions by 2050 (IMO 2050) (United Nations, 2021).
Nations, industries, and societies are of understanding to make changes to reduce pollutions to avoid climate crises influencing the earth.
Shipping and trades on keel are a major contributor of producing unhealthy waste to both air and sea.

The NOX-foundation, PILOT-E and ENOVA are examples of foundations giving economical schemes to shipowners for meeting the non-pollution requirements. This aid is so far ongoing to 2025.

3.6 Green Technology

When I first started to formula my thesis in the beginning of 2021 there have been a significant change of focus in the shipping industry to meet the climate goals. In the beginning there were a quite high amount of information and articles to be found, but from Q2 2021 the information around green technology grew exponentially and became a struggle to limit my research.
The definition of green technology is volatile and can be defined in several ways and therefore I had to make a stand on what I mean with *green technology*. This was of good help when I talked to my informants.
It is essential to have a common understanding for some of the concepts because they are widely used in different hence, both domestic and international and, in literature.
To define Green Technology, we can use the definition from Investopedia:

> *Green tech–or green technology–is an umbrella term that describes the use of technology and science to create products that are more environmentally friendly. ... Examples of green tech include the technology infrastructure used to recycle waste, purify water, create clean energy, and conserve natural resources.(Investopedia, 2021).*

In history we have been through the same *change* going from one energy source to another (without looking at the environmental focus) when going from sail to steam.
In last century in Norway the Government have supported the shipowners and their cooperative with large amounts to build infrastructure supporting operations of steamships.
Today the shipowners are in the same in regards of having to submit applications for economical finances from the government, governmental supported organizations and even funds through European Nations.
This economical support is an important factor to be able to innovate and order new technology without taking economical changes, but it is also a good arena for the ship industry and politics.
This seems to be a special (unique) connection in Norway and Northern Europe in this hence, while it is more difficult to find the same equal systems elsewhere.

3.7 Description of the Research Problem

I wanted to research what we can expect to happen in the shipping industry regarding to find a solution to reach the climate goals, what the education system must do to educate Marine Engineers on bachelor's degree and what the maritime industry expects of understanding and knowledge from the Marine Engineer working onboard.

I have used my own knowledge and competence from my work experience to find relevant and reliable references, and thereafter using research methods to collect and use this data in my research.

My research questions are:

> *RQ 1: Shall new energy resources, like hydrogen and ammonia, be the focus in the study plan for a marine engineer forward to 2030?*
>
> *RQ 2: Can academia prepare and make the marine engineer competitive for meeting the UN's sustainable development goals for 2030 and 2050?*

Research question 1 is a quantitative question with a *yes* or *no* as basics answers, but with complementary answers given by the interviewers.

Research question 2 is a qualitative question with reasonable thoughts on *how* the academia can meet the green wave we now see in shipping.

I will in chapter 7 "Results" present the answers as a conclusion based on an analytic summarizes from the interviews based on table 1 and in chapter 8 "Discussion" will I use theories to discuss the results, in hence to use the results in a study plan.

4 Methods

4.1 Research design

To carry out a valuable research project and to collect relevant information I choose *qualitative method* and exploratory research as the main method.

Through my research I have been in contact with and interviewed several persons and companies with different affiliation to how the education system is built up and working.

My data collection is based on two main research sources: *interviews* and *literature available online and in papers.* Also talking with persons in my daily work, observe webinars and participate at the Maritime Safety Conference 2021 hosted by NMA in Haugesund, Norway have contributed to the research data.
I made a list of potential interviewees who I thought could give me data, perspectives, information, knowledge, reflected answers and thoughts related to my research.
This list became very quickly too comprehensive, and I had to analyse and select based on my own knowledge and inputs from colleagues within this segment to narrow it to nine interviews with eleven interview objects (see table 2 for details).
My results and references are not recognisable and written to be non-identifiably, and therefore my thesis does not need to be reported to Norsk senter for forskningsdata (NSD).
Research methods can be divided in three ways; qualitive, quantitative and mixed methods.
A qualitative approach describes a research problem by exploring a concept or phenomenon and is used to explore a topic with unknown variables and theory bases (Gray, 2018)
A quantitative approach is more systematic investigation of phenomena by using closed-ended questions and numbers to analyse and looking for relations between variables.
My interviews have been with open-ended questions and dialogues to get a true understanding in my questions, and to eliminate misunderstandings. I also had the opportunity to have follow-up questions with them all, even if I never used this opportunity.
The "Results" in chapter 7 and "Discussion" in chapter 8 are based on a mixed method approach with research for answers, opinions and facts which is both qualitative and quantitative (Creswell, 2009).
I wrote the answers and keyword during my interviews on paper and summarized the answers to the different topics, and the results are seen in chapter 7 "Results".

4.2 Reliability and validity

All my interviewees are done in the purpose of the Norwegian education system and have not been considered possibilities international, and all my interviewers are familiar with the Norwegian maritime industry and have relationship(s) to my thesis.
Directedly contact with the interviewers locally, on Teams, one interview on mobile phone and by conservation during the interview state the reliability.

The interviewees summarize perspectives from suppliers of green technology, authorities, representative for Marine Engineers, shipowner, and the education system. I believe this will give a good insight with reliable views.
The answers given by the interviewees will have validity for a certain time until newer green technology is invented and/ or new regulations are announced and declared. It is with a great chance of certain probability I will get the same answers if I made the interview with the same questions and approach several times after this writing.
To make the data collections and answers more reliable I could interview 20 to 50 more persons, but this would take far too much time to implement and process.
It is often referred to *næringen* (the industry; maritime) without further specifications of whom these are, and for my research I have concretized who these are in this individual case, and my selection of interviewers can illustrate *næringen* as expression.
One deficiency in my research and data collection is the lack of inputs from licensed marine engineers who have the experience of operating green technology on ships today. Interviewing them could make a different result in my research, but I choose to narrow my research on how to change the future study plan and opted out these interviewees.
Based on my own experience and another MSc thesis I deselected sending questionaries to interviewers (Hasslan, 2021, p. 27).

4.3 Data collection methods

The preferred method to discuss my thesis is qualitative data, as I want to make a research in what the maritime industry perceives to be in the study plan for the marine engineer.
All the data collections from interviews, literature, web search, seminars and through dialogs with relevant persons has resulted in unison answers.
I made a draft with wide aspect of relevant persons, and after an analytical review I ended on nine interviewers. These nine represent the Norwegian maritime industry in the whole scale, including governmental actors, ship owner, manufactures of products and systems related to environmentally friendly solutions, classification society and academia/ the school system.
Below are the main topics as a result from the interviews in a non-chronologically chapters with briefly descriptions of the topic/ -subject.

The interview was built up with main topics and was highlighted differently depending on the interviewer's relationship to the thesis. All interviewers were presented and affected with the topics. The main topics are listed below in chapter 7 "Results".
I also reformulated, removed, and added questions/ topics during the whole time during my data collections, as I got inputs and new information with my interviews.
Internet, media, articles, magazines, and dialogues during the workdays are also resources for my data collections.

Interviewee	Affiliation to this thesis	Method	Duration in minutes
1	Developing technology and products to reduce shipping emissions. Headquarter in Norway.	Local interview	130
2	Project Manager for zero emission ferries to operate in Norway. Employed in a shipping company operating only in Norway.	Teams	75
3	Technical Manager in a Norwegian company delivering	Teams	70

	advanced, tailor-made systems for new ships or ships with retrofitted solutions.		
4	Professional at a Norwegian education centre (not the same centre as interviewee 5).	Teams	50
5	Professional at a Norwegian education centre (not the same centre as interviewee 4).	Local interview	90
6	A Norwegian trade union, politically independent.	Mobile telephone	75
7	A Norwegian state directorate.	Teams – 2 interview objects	90
8	Developing technology and products to reduce shipping emissions. Headquarter in Norway (not the	Local interview – 2 interview objects	70

	same as interviewee 1).		
9	An international classification society. Headquarter in Norway.	Teams	65

Table 2 Overview over the interviewees. Made by author.

4.4 Limitations of the thesis

As I collected data it became clear that the limitations had to be further defined and specified otherwise it would become too wide and impossible to narrow it down, and I came up with these limitations:

- It must be possible to add and/ or influence on the study plan for Marine Engineers on bachelor's degree in Norway and still be in accordance with STCW based on inputs from interviews, literature available and dialogues with relevant interests (what is possible to achieve within approval by NMA and NOKUT)
- Limited the numbers of informants based on a qualitative assessment and their relevance to my thesis
- Not making research in what to remove or reduce in the study plan
- Answers and dialogues are based on their own experience, expectations, and assumptions to reach UN's goals without references to details on specific details on single objects.

Further are my limitations based on how the education system is currently in Norway with two options to be a licenced marine engineer, either through academia or through vocational school (høgskole og fagskole).

5 Results

In this chapter I have categorized the results from my interviews with *main group* and *sub-groups* with a briefly description of every topic/ subject.
Descriptions are based on information during interviews and literature from different sources like internet, articles, and home pages.
The summary from the interviews is written in a common texture based on all nine answers, and noticeable deviations are only specified and mentioned where it emerges.

5.1 Technology and data

5.1.1 Use of simulations

It is a common understanding from all data collectors that simulators and simulations like Virtual Reality (VR) is a relevant and a good way to acquire knowledge about green technology. There are many simulation possibilities on the marked today offering multiple opportunities, both standard and customized products.
Still, it is important to not abstain the human senses like noise, vibrations, smells, and stress factors the student will feel on a ship in real life, said by one interviewer.
Then there are special simulators specialised for firms that are not available for the open marked. Examples will be simulators for a product delivered to customers like power automation for one class of ships.
Simulators are used for assessments at most educations centers around the world to reduce for instance mandatory sailing period. Simulators have the functions and programs to be used for both formative and summative assessments.
These types of simulators are often for internal training and practice.
Use of simulator for education is to be found in STCW Column 3 of the table A.

5.1.2 Level of autonomy in ships

Autonomous ships were a big topic only a few years ago in the maritime industry.
Yara Birkeland got great publicity on the topic, and Asko ordered sea drones for transportation of cargo between Horten and Moss.

Both Yara Birkeland and Asko have developed autonomous and zero emission ship/ drones to replace truck transport and cargo handling.
None is in traffic yet, but they both are in phases of testing and building with results being expected in 2021/ 2022.
None of the data collectors have a strong belief in or focus on having autonomous ships fully operated in near future. Still the majority believe it can be a reality in smaller scale the next 5 to 10 years.
However, operating autonomous ships/ drones create another topic, optimization of energy. Parameters used for operating a ship automatically gives valuable data for saving energy and time that can give synergy to ships operated by seafarers.
In extension of this is digitization in the shipping. Digitization as a topic alone is comprehensive and very important in all technologies and is highly focused in the maritime industry.
On the other hand, this is too complex and specific to handle considering networking, cloud-based solutions, licenses, IT-security and both soft- and hardware for someone without IT specialties and knowledge. This field of competence is not possible to give the students in this study plan, but IT must be dedicated a focus to have a good understanding on IT.
- One interviewer question on how new regulation will regulate what competence and skill a person operating a ship by remote must hold. In another interview I was told it is by Norwegian federations to put forward a proposal to IMO to continue existing requirements for seafarers. If this will be considered in a new regulation, it means for example, that the operator must have the highest class of licence to operate an autonomous ship over 3000 KW.
One interviewer think that it will be a chain reaction when the first autonomous ship is a reality, and therefore this subject will be relevant as soon as the first ship is sailing.
Further have some interviewers compared autonomous ships with ships equipped with periodically unattended machinery space and dynamic positioning 2/3 (EO, ECO and DP2/3 within DNV standard) as more or less a similar system, seen in the perspective of laws and systems related to get these classifications. Redundance, power managements systems, monitoring and remote-control and access are already familiar to many marine engineers.

5.1.3 Industry 4.0

The maritime industry and operating ships, either with or without personnel on board is a part of the industry 4.0.

The interviewees are in one way or another a part of it and must relate and act to this concept. It is pointed that this is not a subject to the study programme, but it is of greater relevance to be familiar and having knowledge what this concept is, due to a matter of influence this concept has on the industry.

Remote access, remote control and remote operation are today possible, and network will be more important to relate to and understand for the marine engineer. IT security is highly relevant and is of greatest matter to keep the ship operational, and therefore there must be an understanding of this importance when the marine engineer give access to be remoted. The company is responsible for producing instructions and routines to preserve the security matters.

Among several interviewers the COVID-19 pandemic is a contributor to a more digital approach for all of us. Meetings, survey's, revisions, documentations, and trouble shootings by service firms were moved into digital arenas like Teams, Zoom and Skype. This could have been a long way to go if the pandemic did not force it forward.

Several interviewers further stated it was of greatest concern to highlight that a marine engineer cannot be replaced by IT-personal, neither on bord or in a remote-control station on land. In accordance with STCW the person operating a ship is obligated to have a licence and there must be a chain of command. During the interviews it has been mentioned that this regulation is promoted to be continued in the regulations regarding autonomous ship.

A marine engineer should have good knowledge about IT but shall not become a programmer.

5.2 Subjects related to the study plan

The interviewees point out it is necessary to have thoroughly knowledge and understanding in material science, chemistry, and thermodynamics to perform correct operations and acquire good knowledge about green technology.

Several of the interviewees have technical education, even as Marine Engineers, and know these are topics in the present education but want it to be more related and adequate to green technology.

Some interviewees relate material science as the basic knowledge to understand how green technology can make an opportunity and a possibility to make zero-emission ships.
Some of the interviews said it is necessary to look beyond "nærskipsfarten" (short sea shipping) to understand and see what is going on in the fleet around the world to reach the UN's goals. As they say further:
"*It is not possible to recharge batteries from shore or having battery storage big enough to enter and perform voyages through restricted areas, and therefore are the deep-sea fleet having a different focus to meet environmentally friendly solutions."*

5.2.1 Job- and career opportunities

Today a Marine Engineer with a bachelor's degree have several job opportunities on shore after education. Ether the graduated go to sea or not he or she will be interesting for several segments in both the maritime industry and in the non-maritime industry. Examples on places to work and possibilities to make promotions are at yards, maritime service companies, hospitals, power installations, factories and in administration in shipping companies. Typically work titles can be Technical Leader, Technical Manager, Operational Manager, Technical Supervisor, Technical Inspector, Technical Superintendent and Project Leader.
Interviewers said they expects more skills, competence and understanding of the maritime industry from marine engineers with bachelor's degree than marine engineers without. Further they experience more career opportunities with this background.
Without being able to collect data on how many students staying on board and for how many years, it is a lack of Marine Engineers in the near-coast fleet in Norway based on inputs from the interviews.
More of interviewers encourages the education centre to look at options to make the study plan equally relevant for sea going personnel, maritime industry and (on shore) industry.
As one said: *Look at the possibilities to recruit from land to sea!*
Several of the interviewees has a technical background from sea or/ and having personnel with this background in their organization.
Some interviewers pointed out that they often perceive a marine engineer as result-oriented persons with abilities to perform under pressure, and these were highly valued properties they looked for in a recruitment process.

There is a certain acknowledge among the interviewers that the time for “traditional” engineers’ tasks on board might be over, and it is more needed to manage the systems on board.
The academia and the marine engineer educated from the academia are both products (and factors) in the maritime industry and must be competitive to sustain in the *market*. Several interviewers mean there must be some adjustments in the marketing and study plan to recruit students to this education. It is mentioned, as suggestions, to look at the Danish system, rename the study program, rename the title when graduated and pay more attention on job opportunities to raise the reputation. It was by some said that the Norwegian “maskinist” is associated with something mechanically, oily, and manually work performance.

5.2.2 Project Management/ document processing

Few industries are more strictly regulated, neither on national level and/ or on international level and it is a complex and bureaucratic to navigate within.
To build a new ship, to retro-fit existing ship or to install new equipment(s) is a process with engineering, applications, tender, contractual negotiations, risk analyses, documentation, verification of flag state- and classification laws and must be performed by standards.
The interviews have a common perception this is unfamiliar for most common Marine Engineers and this scope of work is prepared by and followed up by external companies.
However, some ship owners see the value of having this competence within own organization and use sea personnel to the whole or parts of the process.
Interviewees mentioned they sometimes meet technical challenges of understanding the *workflow* by the engineers on board when installing new products on bord.
Also, pointed out by interviewers, the understanding of meaning in the texts in e.g. classification certificates and notifications seems from time to time be lacking.
Some of the interviewees says they often meet challenges after a project ends when the ship and installations are to be in operation. Further is Failure mode and Effects Analysis (FMEA) said to be a good example to understand the operation of the ship and this documentation is often unfamiliar to marine engineers. This documentation must be revised, or even do a new analyse, when the ship is refitted for new propulsion system(s).
Two interviewers think academia should investigate to interrupt closer with companies in the maritime industry with international arenas. Several of these companies have their own, specialized

persons working with QA, laws and regulations and have unique competence in this field. Some companies also have representants in different committees in IMO.
Better understanding of ISM-code is highly relevant for mostly all operations being carried out, both on administrative and operationally levels.

5.2.3 Leadership and management

Leadership or a leader have such a generally definition from military literature to show concern for employees.
Among the interviewees it was a generally statement that leadership is a relevant topic and necessary for achieving success as a Marine Engineer.
Underlaying this answer is that topic *leadership* includes cultural understanding, organization theory, human factor and behaviour, ethics, and contractions between people.
This is, as some of the interviewees said, a skill of great importance is to *know how* and *know what to do* when challenges arise.
One other interviewer highlighted the importance of leadership and management skills in the study plan since the marine engineer may end up with personnel responsibility among other responsibilities. Management is mandatory topic in the study plan accordance to STCW, and the interviewer continue: "*Maybe it is a good idea for the academia to see if it is possibilities for the students to practice more cultural leadership instead of only be lectured it?"*

5.2.4 Oral & written technical English

Even if many of the suppliers and developers are Norwegian or Scandinavian, most companies deliver documentation in English. This includes the mimic's and screens configurations. Some ship owners request documentation in Norwegian text, but it is rarely and an extra cost to the buyer.
The interviewers inform the language can be challenging with technical terms and terms related to electrical- and automation related systems.
Another point, they claim, is that there is a "generation gap" and the younger Marine Engineers are more familiar with the mentioned terminology than their older colleagues. They believe this has to do with a generation growing up with computers and technology, and since it's mainly described in English.

5.2.5 Methods for learning green technology

All interviewees are representative in varied education and specialization degrees and programs from various education facilities, with MSc as the highest degree.
They had inputs in how to make the study program more *professional* in hence to implement our discussed topics, without going in details or to specific some scops.
Some of them suggested to look at education systems abroad, and Denmark and Netherland are mentioned by two persons as examples of education programs with prestige.
Some suggest a form of internship in a shipping relevant company could be considered, together with research tasks prepared by the education centre. And a type of trainee program with tasks related to green technology and in the hence of a synergy-effect between the academia and the maritime industry.
All the interviewees were asked if their company are willing to lecture and/ or receive visits from the academia with students, which they respond positive to.
One interviewee knew several companies with laboratories, workshops, and test facilities within these topics that most possible could be worth a visit. Further, he said, are there many factories under construction in Norway within the segment of battery and hydrogen/ ammonia that probability have relevant experience related to the maritime education system.
Stronger cooperative relationships between the (maritime) industry and academia are strongly recommended by the interviewers. This was, expressed by some of the interviewers, something they missed during their own study time.
More research on up-to-date thesis and topics is needed to be in front of green technology is a repetitive statement by the interviewers.

5.3 Topics for propulsion

5.3.1 Nuclear and steam

Surprisingly many said nuclear should be considered closer and raised as a topic together with steam.
The interviewees reefer to nuclear as a non-emission energy source with potential to operate ship.
Technology for nuclear ships is existing e.g. submarines, icebreakers and air craft carriers operating by military.

The safety barriers, how to operate and maintain fuel cell with nuclear, knowledge of hazards using nuclear and how fusions occur are themes to learn in this topic.

According the interviewees splitting atoms and science within advanced nuclear is not relevant to know for Marine Engineers.

Steam is also an important part to be kept as a relevant topic set up against steam for several reasons:

- Steam is produced in a boiler, simplified explained, either by nuclear, fossil fuel or hydrogen fuel cell.
- Theory for steam is relevant and reversible in other topics, such as refrigeration, heat, ventilation, exchangers and transporting of energy.

Among the interviewees there is a common statement that steam is still an import topic to green technology and must therefore not be underestimated.

As one of the interviewees declared:

- *"If you know and understand the cycle of steam you will understand most of the other systems on a ship."*

5.3.2 Hydrogen

The interviewees are suppliers of Hydrogen fuel cells, ship owner with focus on Hydrogen and different authorities working with the purpose for implementing or facilitate it as a resource, with documentation, regulation, or teaching.

Hydrogen is now presented as *the change maker* both on- and offshore to reach zero-emission by 2050, and it is a big political willingness to prioritize this by economical supports through research, funds and applications. Today's hydrogen innovation is mostly concerned to production and storage, and little concrete research or innovation due to fully operated propulsion solutions.

It is not possible to operate a ship on Hydrogen without an infrastructure and a functional logistic, but the interviewees want more concrete innovation on Hydrogen as energy source for propulsion.

The interviewees agreed that Hydrogen is a good and environmentally friendly source playing an important role to reach the UN's goal, and it is of greatest importance to continue research and development related to Hydrogen to be used on ship.

As this thesis was written and data was collected through interviews there was none fully operated ship by hydrogen.

The interviewees showed some interested factors in a quite common way how the maritime industry sees on Hydrogen as the *change factor* in green technology.
One challenge, as they see it is the infrastructure to operate ships on Hydrogen. The production, transportation, storage, and location for fuelling are all factors that must show to environmental accounts to be proven as a clean product.
MF Hydra was recently elected *Ship of the year 2021* by Skipsrevyen with following statement from Gustav Erik Blaalid, the jury's leader and editor-in-chief of Skipsrevyen:

- *The combination of hydrogen and electric operation makes MF Hydra one of the most environmentally friendly ferries in the world. Hydrogen, which is a zero-emission fuels, also shows promising properties to be an alternative fuel for ships, even over longer stretches of sea.*(Norled, 2021)

MF Hydra is a result from tender given by Statens Vegevesen with a definition as a project to learn within hydrogen technology and one specification is that the route is to be fueled with hydrogen minimum 50%.
As one of the interviewees points out based on the innovation related to fulfill hydrogen propulsion and MF Hydra:

- *"It might take some time to go from this project to fully operated on hydrogen even with subsidizes in Norway….. (!)"*

The classification of hydrogen depends on where the fuel cells is operated and located. On shore, for commercial use it will be regulated by NEK 105 and it seems to be incorporated, on sea within the International Code of Safety for Ships Using Gases or other Low-flashpoint Fuels, shortly named the IGF Code. This Code was mandatory from 1st January 2017 for personnel working on such ships, e.g ships fueled with LNG.
The interviewees are not convinced that this code is the right code to address hydrogen, and other new fuels like ammonia, and refers to the code as too general for new fuels.
Therefore, they believe new regulations and safety criteria will come successively with operation experience.
Personal and companies operating hydrogen and ammonia will have the opportunity to influence and "write" laws and regulations regarding these fuel sources.

5.3.3 Ammonia

Even if ammonia is a separate product with its own specifications and must be handled as a product, it is by the interviewees and in the science of a zero-emission fuel collateral with hydrogen peer today.
Two or three of the interviewees find ammonia interesting as a resource in propulsion and refer to innovations and tests with engines running on ammonia, most of the interviewees mean ammonia and hydrogen is equally at this stage in innovation. They are e.g. similar in how to be transported, storage and handling.
Referring articles, it seems like a general perception to describe hydrogen and ammonia as common fuel when it is on a simpler description basis.
Based on this feedback I found it relevant to merge these two fuels in my discussion.

5.3.4 Fuel cell

Fuel cell is, simplified told an electrochemical cell that converts the chemical energy of a fuel and a oxidizing agent into electricity through a pair of redox reactions. Fuel can be hydrogen and oxidizing agent is often oxygen or air.
Fuel cell is not new as an innovation and was invented in 1838, and in 1932 fuel cell with hydrogen and oxygen was invented.
Fuel cells have been in use in all industries for decades, and as we know, is mostly going to be a solution in shipping

5.4 Topics for auxiliary systems

5.4.1 Battery technology

Battery is a subject most of Marine Engineers and people related to maritime industry has been familiar with the last 3-4 years due to the electrification of many ferries in Norway. Also, the interviewees are in one way or another, involved in batteries and electrification of ship. Either directly through their daily job or indirectly as a part of their job.

The interviewees think battery, as a distinctly topic is not relevant to have in a study plan due to three reasons:

1. Battery is an energy storage, and not a producer of energy.
2. Battery is a temporary solution in hybrid systems until newer, zero emission technology is implemented on ships.
3. Batteries are products delivered and mounted on board, with minimal supervision by a Marine engineer.

But, on the other hand it is of relevance to know how to operate and know how a battery is build up as a product, the components and safety barriers and systems.

In Norway there have been two major fires in batteries on board ships with large battery capacity for propulsion. MF Ytterøyningen was a car ferry retrofitted with hybrid solution and PS Brim was a new building passenger ship with hybrid solution. The feedback from both accidents refers to, among several other, lack of knowledge how to extinguish a fire and potential of unreleased energy when batteries are on fire.

Two examples, State of Health of batteries (SOH) and High Voltage (Course) are mentioned by some interviewers to be concepts marine engineers have been introduced to with new battery technology. SOH is annual requirement by NMA and DNV to remain in class and be licensed with national certificate, while High Voltage (Course) is a mandatory course to be licensed engineer (with some national exceptions).

5.4.2 Energy efficiency

This topic is giving a lot of acceptance from the interviewees in similar way:

- *"Energy efficiency is important to understand and "live after" to see the whole picture in the chain value of energy."*

What is done in one hence can and will influence in another hence and may influence the whole balance.

Many interviewees had examples from own experience (ship related) and telling they are experiencing this often by persons operating, often technology with screen panels.

This topic is an umbrella for many affiliated factors as: fuel economy, speed (in knots), manoeuvring, maintenance intervals and wear on components.

There are several energy efficiency documents for ships, as one interviewee say, but it seems to be poor understanding for several marine engineers what these certificates means. The certificates he refers to are, among several, International Air Pollution Prevention Certificate (IAPP), International Energy Efficiency Certificate (IEEC), International Oil Pollution Prevention Certificate (IOPP), International Sewage Pollution Prevention Certificate (ISPP)and Ship Energy Efficiency Management Plan (SEEMP).
Certificates like these have several functions, responsibility, and commitment to flag state, classification notation, insurance and regulations and have big importance to operating a ship. And must consequently be well understood when rebuilding or implementing new (green) technology.
It is pointed by one interviewer that this subject is more important in the design phase of a ship/ re-building and is a topic hard to cover in a study plan due to its complexity, but still essential to know and be familiar with.

5.4.3 Scrubber

Scrubber, also related to SCR and water-washing systems have been modified since it was introduced to the marked in the beginning of the 2000's.
Scrubber can be used for emissions from fossil fuels and LNG due to both emissions have non-environmentally particles released during combustion.
There are two ways of collect and treat the waste from the scrubber in so called *closed- and open loop.*
In *closed loop* the waste is collected in suitable containers or tanks and treated on board de-carbonizing e.g. or delivered on shore for further treatment.
A Scrubber is relatively simple to operate for personnel, but documentation for operating is vitally for correct execution and is strictly regulated by IMO and is a check point for a Port state control.
Newer scrubbers remove more particles than older, are more efficacy and is still needed if the ship operate on heavy oil fuels with sulphur.
In areas with restrictions on sulphur contents, e.g. SECA, scrubber is a solution to meet the laws for entering this area.
Some interviewers see scrubber as a temporary solution to be zero emission, while some see scrubber as a complete solution.

The main differences are related to were in the maritime industry the interest is. For example, is scrubber (SRC and related systems) more relevant as a product to the industry producing solutions for main purposes, rather than the industry producing hybrid solutions to reduce emission.
Some interviewers told the delivery capacity on land and functionality for Scrubbers have been significant smoother and easier the last couple of years.

5.4.4 Hybrid solutions

Hybrid is something that emerges when crossing or assembling several elements, and has become a familiar expression for the most among us the latest years e.g. hybrid cars.
Hybrid is a solution to power a subject incorporating renewable energy.
For hybrid ships renewable energy are electric batteries, hydrogen fuel cell, and solar and wind power typically examples we have today.
Hybrid is not an unknown topic for my interviewees, and they were all know with the concept on ships, and therefore this topic not got necessarily elaborated during the interviews.
Further it can imply that hybrid may be a temporary solution to reach the UN's emission goals, or even a permanent solution and therefore it is a general understanding from the interview's hybrid should be a topic. But with more focus on *why* and *how (criteria's)* hybrid solutions are made.
One interviewer implies there can be more hybrid solutions for the deep-sea fleet due to entrance to ports and special areas (ECA, SECA and more), and less hybrid in near-coast fleet. He refers to ships like Color Hybrid and MS Fridtjof Nansen.

5.4.5 Power Distribution

Some interviewees mention *power distribution* as a topic to teach the students more about. The background for this proposal is not to be e ship electrician, as they say, but to learn more about how power is distributed on board and safety protections related to power distribution.
They specify this, independently, they have a common experience there is some lack of understanding of the system due to newer technology. One interviewee mentions that-, he believes some of the engineer's struggle when components has been smaller and no longer visual in switchboards and digitalized.

This feedback matches other interviewees when they mention *programmable logic controller (PLC), automation, management systems* and *high- and low voltage systems.*

As a Marine Engineer and Chief Engineer, you have the responsibility for the electrical system onboard, and if you do not have a ship electrician to delegate the tasks to it must be performed by service personal with the right competence.

Battery-hybrid (may) have several transformers, conductors, switchboards, rectifiers, and converters compared to conventional ships. This can create a challenge to troubleshoot by schemes and drawings – which are normally physical components to "search" for when troubleshooting. Interviewees with direct contact with engineers agrees on the statement.

5.4.6 Heat, Ventilation and Air-Condition (HVAC)

HVAC, Heat, Ventilation and Air Condition is a major system with a lot of parameters to follow up onboard, and the system is getting more comprehensive as the green technology moving forward. It also includes systems to control transportation and utilize cooling- and heating from e.g. propulsion motors.

This is a topic which most the interviewees say is import for a Marine Engineer to understand how to operate and control to keep an energy balance.

Wrongful operation of HVAC may cause increased energy consumption and wear of equipment's.

Further it is mentioned by some interviewers that HVAC is getting more complex and digital than it used to be, and therefore the understanding of the processes might be more important to know rather than the equipment.

5.4.7 Other energy sources and topics

Below are other energy sources and topics mentioned by one or several interviewers, without any further explanation:

- Liquefied Natural Gas (LNG)
- Liquefied Petroleum Gas (LPG)
- Ethanol, Dimethyl Ether (DME)
- Biogas
- Processes due to clean ship (wastewater, ballast water, sewage)

- Synthetic Fuels
- Solar Panel
- Mixed fuel
- Heat recovery
- Sail
- Aqua culture
- Hydrotreated Vegetable Oil (HVO)
- Offshore wind turbines
- Carbon Capture and Storage (CCS)
- Making the education more relevant to higher positions like surveyor and superintendents
- Quality and assurance (QA)

6 Discussion

Based on the interviews it seems clearly that there are high expectations by the maritime industry for the marine engineers operating green technology in the years to come.
This puts pressure on the education system to produce and feed the industry with the right competence and skills of the marine engineers educated at academia.
It is always possible to add more to a study plan, but the challenge for the academia is to remain equal amount of time spent on lecture and teach green technology to students.
Interpreting the results and answers it seem to be too extensive making a list which constitute concrete topics that make the study plan embracing green technology in all matters.
There is a common perception among the interviewer's that green technology will be in constantly development and the study plan for marine engineers must, in some way be flexible and dynamic with the maritime industry.
Laws and regulations, either national or international cannot follow up the speed of development in this industry and therefore should all actors be solution-oriented and in interaction within other.
It is a challenge that laws, and regulations cannot follow up the development in the industry, but on the other hand it is a great opportunity for the academia to influence and be a contributor to design new laws and regulations.

The results from my research points out numerous common and individually answers on different topics and it is not possible to add or even get most of these topics in a three-year study plan. Academia, as any other contributes to the maritime industry must produce product(s) to be competitive and keep their existence.
To meet these expectations from the maritime industry the study plan and the teaching method should be reassessed, flexible and innovative.
One definition of innovation is based on Joseph Alois Schumpeter's book *"The Theory of Economic Development" from 1934* (Croitoru, 2012, p. 137):
"A new product, a new service, a new production process, applications or organizational form that is launched in the market or used in production to create economic value."
In business and military strategy, the *unknown* is a *known* factor, and we can transfer this factor to the education for green technology.

6.1 Technology and data

Simulators are already a well-known and well used tool to both educate and doing assessments, but this research sees the opportunities and possibilities to use simulators and simulations in the hence to learn green technology.
It is no longer questions *if* ships are going to be autonomous and operated from land, but the question is *when*. And it might happen in short of time based on articles and literature on this subject, even if some interviewers were a little more reticent.
There are many different types of simulators and suppliers of simulators providing maritime programs around the world, with general lay outs and specialized systems.
Gradually it will be a topic in the maritime industry what qualifications operators and owners must have to be autonomous, and this may change the education significant if major changes are assumed.
The laws and regulations due to autonomous ships are yet not implemented, but Det Norske Veritas have prepared a class guideline for autonomous and remotely operated ships (DNV, 2021) which can be seen as a draft for what to expect in operating autonomous ship.
Perhaps, as a thought, simulations will be a key role in (an eventual) certification process for a remote operator.

Investing in simulators and simulations systems and equipment's are costly and therefore must the investment be appropriate.
Using simulator is one method to cover many topics and perform maritime assessment in accordance with STCW.
Assessment procedures in STCW Code 2010 says:
Where simulators are used to assess the ability of candidates to demonstrate levels of competency, assessors shall ensure that: (……)
Many articles and research studies on this subject gives a foundation of pros and cons using simulators and simulation tools, and most industries (air, car, military, construction/ engineering, medical e.g.) use simulation tools.
Simulation is cost effective if the alternative is to perform the exercise in real environments and it is possible to create scenarios simultaneous without risks for humans, environments, and pollutions.
Horntvedt and Arnseth (2013) says that the simulator itself offer little in terms of learning, emphasizing that what is simulated is far more important than the simulator.
From briefing, through scenario, to debriefing: the maritime instructor's work during simulator-based training (Sellberg, 2018) and *Telling stories from the seas* (Sellberg & Wiig, 2020) are studies looking on how simulator-based training can impact and influence the learning outcome.
If the student will have a positive or negative learning outcome from the simulator training is of big impact depending on the instructors work of organization and facilitating the learning activities, and the instructor's knowledge to the training scenario may influence the learning outcome. Further may many instructors have experience in what they instruct, e.g. a chief engineer is an instructor on the engine room simulator, and may influence the simulator use with own experience from the sea.
This might be a challenge if the academia uses simulations for green technology, e.g. hydrogen fuel cell on ships, and the instructors do not have knowledge or experience in fuel cells.
From storytelling we know the face-saving work (Sellberg & Wiig, 2020) in debriefing situations and it might occur something similar from instructors if they instruct unknown topics.
Assessments in the Zone of Proximal Development, ZPD, (Meyer & Turner, 2007)is defined as the "distance" between what the individual can do when acting alone and what he or she can do when interacting with a "more competent peer", and this is important to be aware of if this distance in a new simulator and/ simulations tools become a reality without training the instructors.
It is vital to give the teacher or instructor the right training and competence to be able to make a "more competent peer" and the ZPD minimal for making simulator training best possible.

Assessment is one criteria in the STCW that has to be documented to pass the education.
Operating ships from land can be more family-friendly, less travelling for seafarers and the possibility to recruit more females and become gender equal.
It should be of interest for academia to follow this theme since this may be an opportunity to influence this topic and utilize the competence and knowledge they already possess from simulators and theory.

6.2 Subjects related to the study plan

Subjects and topics within this context are more widely than the rest of the answers from the interviews, but still, this might be the essence in how academia educate their marine engineer students differently comparing vocational schools.
We know the difference in educationally and pedagogically terms by these two education systems are, but my results show that there are expectations of even more skills and competence in this subject.
I was somewhat surprised by the engagement from many of the interviewers when I asked about these subjects. It seems to me that method, research, and management are valued topics in the maritime industry, and that they want more focus on the subject in the study plan.
Based on my results the interviewers seemed to be more concerned on *how* the students can acquire competence in green technology rather in *what* specific topics based on the constantly changes and developments.
Clearly this is an advantage for academia when method, research and management as subjects already are topics in their education context and existing study plan and well-known topics for the teachers.
Hydrogen and ammonia is a big focus these days as this energy source is non-emission, but as my research can show the interviewers are not convinced these will be the main or biggest contributors to reach the UN's goals the next decades.
The interviews have resulted in suggestions and examples of energy sources and systems to reduce emission and be zero-emission.
Fuels with new contents, fuel cells, scrubbers with new technology, fuel-mixes, hybrid-solutions and focus on reducing our footprints in the whole chain value is not making one or two particularly energy sources more relevant than others.

It must also be considered to be in according to STCW and not narrow it down to Norwegian near-coast possibilities.
Therefore, should neither hydrogen nor ammonia be highlighted specifically as focus on a study plan, but instead be consider as a main contributor to make ships emission free.
"The opportunities must be provided to constantly develop their knowledge and competences in dealing with ships with a variety of fuel types or regardless of energy sources" said Mr Odd Rune Malterud, ITF Maritime Safety Committee Chair (International Transportation Worker's Federation, 2019).

While the development of green technology is ongoing, there is no doubt there will be many new energy sources and topics the next decades to cover in the study plan.
It will require a lot of economic costs, effort, and work to keep the study plan continuously updated on what is going on in the maritime industry.
It is of same reasons not possible to educate teachers continuous in the hence of making new and updated lessons and lectures.
Turning the academia to be more of a *facilitator* in the education should be considered. Using the students and their partnerships in the maritime industry bringing knowledge *to* the academia can give synergy for all parts.
This, on the other hand, will require commitments in the academia management to support with financial- and time resources.
Today the academia already has, in one way or another, many subjects and topics from my research, but as assumed by the interviewers the development in green technology are accelerating too fast towards 2030. Making one or few teachers responsible to update lectures can lead to making the study plan static and out of date.
Rename and/ or change the name of the education, perhaps with *technology*, *green* or *manager* in the text together with an innovative study plan and showing to relevant cooperation partners in the maritime industry, might increase student applications to this education. Even students not considering a carrier on sea could consider applying to this program.
This could also be great networking with potential job opportunities after graduation.

6.3 Topics for propulsion and auxiliary systems

These two topics intertwine more and more every day as new green technology is developed.
For example, a hybrid solution embraces both auxiliary- and propulsion systems either it is equipped with combustion engines, hydrogen fuel cell or electrical charging from land.
Therefore, are these two topics merged into one discussion to include most of the results within these topics from the interviews.
The newbuilding programs and order books world-wide is still showing a majority in order of ships with combustion machinery with fossil fuels as main energy resource. These ships are to be delivered in 1 to 2 years and have normally a lifetime cycle before scrapping between 20 and 25 years (Espeland, 2021).
Even if multiple companies are looking at solutions to reduce emissions it will be necessary that the marine engineer can operate machineries with fossil fuels for many more years. The need for knowing and operating conventional machinery will remain for many decades even with focus on low- and non-emission goals.
The study plan must therefore have topics like today regarding machineries and propulsion, but the scope can be reduced and be more general in highlighting what is auxiliary and main systems.

My interviews also point out steam and nuclear to be two possible and essential topics within green technology on how to reach the UN's goals.
Steam is a topic including most of the elements in the process to move and electrify a ship in all it's operations and conditions. It is a topic with widely possibilities to add and remove elements in the study plan in hence to support other topics in the study plan.
Nuclear, as an energy resource is used to sustain the (steam) process by turbines producing electricity and shaft power. Nuclear is emission free but is associated with high danger to humans and the environment if the safety systems fail.
Steam as process can be seen relevant to other topics within sciences like thermodynamic, materiel science and processes in HVAC to mention a few.
Components like turbine, condenser, PLS, safety systems and monitoring are comparable with wind-, wave and hydrogen/ ammonia related technology.
Green technology based on energy sources like hydrogen and ammonia will require safety system comparable or much alike with the IGF Code, a code with basis from steam and nuclear systems.

Producing green hydrogen, ammonia or other non-emission fuel sources demands large amounts of energy, and per today waterfalls and nuclear are two of few possibilities to accommodate this type of production. Turbine theory can be continued from the steam process to wind- and water turbines.
Steam as a topic is well implemented in the study plan and are familiar to personnel with technical maritime background, and the potential to adjust this subject in relevance to green technology could be both interesting and beneficially for the academia.
Few other institutions have the knowledge and competence within steam and have the possibility to make synergy between sea and land.

Battery technology, energy efficiency, scrubber, hybrid solutions, power distribution, automation, HVAC and other proposed topics from the interviews are all relevant and should be considered in a study plan.
All these topics have common denominators and have impact on the emission and footprint from the ships.
Through my interviews with those of them who are related to operation of ships, it came out that there is a poor understanding among marine engineers when new, green technology is installed on board on ships.
The basic knowledge and understanding within power distribution, automation and battery technology is relatively simple and are often not seen in context.
In the study plan these topics are covered today and should be well known by marine engineers, but it seems to be some mismatch or gap between education and practice.
This variety may be caused of rapid development in these topics like complex and fully automated system with little insight and/ or influence by the marine engineer, lack of training and introduction, different systems and products within the same company and non-updated documentations.
On less complex (and older) ships it is easier to get an understanding of how systems are connected by following system by system and visually observe components and their functionable operations, together with drawings and documentation.
Looking at a re-build hybrid ship there are both new and old components connected, earlier manually operations have become automatically, and the marine engineer is no longer admitted adjusting parameters due to password requirements belonging to the manufacture(s).

Finn.no is Norwegian online marketplace that, among other things, mediates job advertisement for private individuals and companies where I found this text in advertising for 1. Engineer (Finn.no, 2021):

"Competence in newer propulsion systems will be emphasized."

This is interesting reading because, it is not a concrete qualification nor a requirement to refer, but still a wanted competence.

Treatment of waste produced on voyage demand systems that monitor and processes in accordance with laws and regulations. Cruise ships are now close to carry 7.000 persons on board, so these systems require competence in operation and distribution for further treatment.

The awareness of environmental footprint for a passenger or charterer caused by their travelling or trade is getting more common, and for a shipowner it is vital to present "a clean ship" to sell their services. *Friends of the earth* is one example of an organization with an open webpage customized to compare cruise companies and their environmental commitments.

Looking to Norway we see environmental requirements as standards to be weighting in a tender process. If it is a public tender the Government has the opportunity to speed up and influence the non-emission demand.

Methodically approach to systems like class- and flag laws and regulations, ISM Code and documentation requirements can contribute to a better understanding of the operation of the ship.

"We must teach them how to do this knowledge, without requiring that they 'know' it already. In some sense, they must produce their lessons before they know them. Our understanding of understanding in matters of instruction takes us to a primordial site of social reproduction."

(Macbeth, 2011, pp. 438–451)

6.4 Learning in maritime contexts

To involve and make *peers* (Meyer & Turner, 2007) and concrete partnership to the maritime industry with ongoing evaluation can be one approach to be updated at all time.

For example, it could be an exchange cooperation between the academia and the maritime industry where students spend a period in the study plan with specific tasks to perform. As written earlier most of the interviewers are positive to exchange between them and academia.

This can be seen as a task for the teacher and academia taking the role as *The Innovation Gardener* and *The Innovation Challanger* (Darsø, 2011, p. 73,75). The main tasks in these roles are to develop the relational competence and building a solid knowledge base in the group.
Bringing experience “back to school” can contribute to collaborative work.
When returning to class the student could share the experience with the class and teacher as a project or presentation. Bringing knowledge and experience back for further study is an effective way of learning (Hattie, 2012).
Research in classrooms has shown that group work most of the time is quite unproductive (Karen Littleton & Christine Howe, 2010). The teacher or lecture must be aware of this phenomenon and guide the students even if it is assumed the students work together effectively.
During the interviews many referred to the multiple different working- and education hubs and projects that are ongoing on national- and international levels, also linked to IMO. By searching in articles and on internet I found many hubs and projects within the maritime industry. In fact, there are so many it will be difficult to make a summarize of them in my research.
It will demand great sources in the academia to be updated with international laws and regulations, and the complex and scope of changes, like in autonomy and environmental areas, will probably become comprehensive the next decades.
Cooperation with companies with strong resources and expertise within this segment by lectures and assessments, can both release teacher resources and give the academia insight in what is ongoing in IMO right now, and what to expect of changes.
One hub or a project may often consist of many different actors, and often with diverse backgrounds, interests and geographically locations. If we can call these actors for *team*, we know from research that teams mostly will experience some form of conflict. This can be related to members inputs/ views not reaching the rest of the team (Assmann, 2008, p. 122). Research have also found that teams with different backgrounds are more creative than teams which are homogeneous. Darsø recommend more leadership when homogenous persons are put in team (Gulbrandsen, 2018, p. 21).
In this texture the many hubs and projects that are ongoing should be lead and put together with focus on relations. The management at the education center should further consider who to be involved in the hubs and projects.

If the academia wants to become more innovative in teaching, and make interactions with the maritime industry, it might be of interest for the teachers and lectures to create a common pedagogically framework.

Today the academia perform mostly lectures by the teacher and the students are to ask questions and/ or to do studies until next lecture, sometimes combined with some type of assignment. Changing this typical teacher role and turning to a more supervisor role can scaffold students in close collaboration. As an example, to scaffold; give the students basic knowledge of material science and thermodynamics, teach them how a scrubber is working by using the basic knowledge from material science and thermodynamics and then perform tests in a simulator with supervision from a teacher. The teacher can be *The innovation Conceptualizer* (Darsø, 2011, p. 75) illustrating information and knowledge in different ways, while the students may take the role as *The Innovation Jester* (Darsø, 2011, p. 73) as they ask questions and stimulates the group.

This will require work and time in constructing a complementary lesson plan in an already busy working schedule for the teachers. The benefits of putting time and cost in doing this is that scaffolding might contribute to exploratory talk and interthinking, and greater possibilities to avoid "groupthink" traps.

If the academia wants to increase applicants and be relevant for students not seeing their selves a carrier on sea, the study plan and study name must reflect this.

Students applying this program must get an understanding before submitting an application for the program, both by the name and the study plan that this program can give the student a carrier both on sea and on land.

There are possibilities with digital lectures, networking on simulators, monitor ships online and getting information in so many differently, pedagogically forms that opportunities seem infinite.

Looking at hydrogen as a subject in this context, the theoretical and physical education can be presented in several possibilities than before: lectures performed on Teams or similar by cooperates producing fuel cell, different sources of hydrogen, safety equipment related to use of hydrogen and cooperates handling the logistic and delivery of hydrogen. Streaming of tests from laboratories on site at the producer or yard, streaming from a ship and/ or a powerplant using hydrogen as a fuel source, and hear with companies who is considering investing in hydrogen or ammonia.

Doing this facilitation by the teacher with support of students, it may be possible to embrace most topics related to hydrogen, getting the newest competence and knowledge on hydrogen from the maritime industry and be more able to presume *what is next with hydrogen*. This information can

be used in simulator exercises, group works, presentations by students used as substrates for next lessons and it is relevant for both sea and land-based operations. Both formative and summative assessments are possible to implement in these subjects.
Feedback is important and must have a central position in develop a pedagogical framework within green technology.
Continuous evaluation on regular intervals or periods, e.g. perform qualitative evaluations on time scheduled bases (week, month, quarters, annual) or after ending a topic or an assessment will be interesting and valuably for making modifications and adjustment in hence to keep the topic and the quality of teaching relevant. This evaluation must also be valuable for external peers.
Another challenge forward is if the marine engineer should be a professional with skills in handling mechanical work like valve adjustments, perform piston overhaul and complex maintenance jobs or be a professional with skills in process operations, supervision and manage maintenance.
If we look at the near-coast fleet the engineer is often the only person in the technical apartment on board, with limited time and equipment to maintain machineries alone. In collective transport the time can often be a challenge when the ship is in traffic most of the time.
Equipment for both main- and auxiliary systems has over the last the years become more advanced with more soft- and hardware and requirements of special tools and equipment's.
Service engineers are therefore often used to perform services that normally was carried out by the marine engineer before.
Guarantees by manufactures are also strictly regulated, and claim reports can be the only way to report failure in the beginning after an installation. If it is performed some kind of action on products by personnel without the right authorization from the producer, it may cause reduction in warranty permissions and economic issues.
Normally is a guarantee period between 12 to 24 months, but there are some examples of batteries delivered with 10 years warranty. This can give the marine engineer limitations and challenges to learn this product and its functionalities.
Lave and Wenger (Lave & Wenger, 1991) says learning primarily takes place through participation in social practice, where the individual must adopt to different types of languages that exist in the institutions.
Students who are used to collaborating and being lectured by the maritime industry and teachers through the whole education, and a study plan that reflects this, will be able to learn the languages and jargons when entering the job market.

Both formative and summative assessments are used to examinate and evaluate the student during the program, with the European Credit Transfer System (ECTS) rating scale A to E (A is best and F is failed) and grading by passed or failed are used.
It is possible in accordance with STCW Convention and Code to change many of today's summative assessments to formative assessments and to identify aspects of learning.

7 Conclusion

The results from my interviews show how comprehensive, complex, and specialized the study plan must be if it should cover all elements and subjects according to the maritime industry to meet the green technology. This is neither realistic nor feasible to meet within a 3-year study plan.
Consider the green technology will develop, laws and regulation will change and be updated constantly within the next decades, the study program should be flexible and innovative.
Several interviewees suggest developing more in *science* to make the students compatible in system- and distribution understanding with an underlying understanding of knowledge.
Based on my research and in my discussion, I have found out that hydrogen nor ammonia should not be the focus in the study plan for a marine engineer forward 2030 (research question 1) and further I believe the academia can prepare and make the marine engineer competitive for meeting the UN's sustainable development goals for 2030 and 2050 (research question 2).
A stronger commitment with the maritime industry may have several benefits, both for the academia, students, and the maritime industry.
Students educated in the academia with strong cooperation with the maritime industry, will probably have a benefit for jobs and carriers on sea and land. In Norway it is now being built battery factories, carbon capture storages and factories related to green technology which need personnel with this competence in addition to ship operations.

8 Recommendations for further studies

My research has discovered some insight of what the maritime industry believe is relevant to increase competence within to reach goals for 2030 and 2050, or before.
But the technology innovation is speeding up and accelerates fast in years to come, and it is important to be updated at all time to be competitive, both as an education center and student.
Further studies should look at the Danish education system, raise the reputation for Marine Engineers in society and how to make bindings between education centers and the maritime industry and see if there are possibilities to make academia the center of maritime hub.
In the end of my writing on this thesis it was a press release from Maritimt Forum announcing a cooperating in the maritime segment to look into how the educational institutions and the maritime industry can meet the need of digital competence together (Maritimt Forum, 2021).
Results from this project are to be announced spring 2022 and will be of interest for (possibly) further studies and to compeer with my research.

9 Glossary and definitions

Chief Engineer	The highest rank for a Marine Engineer and responsible for the technical department on board
De-carbonizing	Reduction of carbon
DNV	Det Norske Veritas
ECA	Emission Control Area
Energy	The capacity for doing work
FC	Fuel cell
Fossil fuel	Energy source made from decomposing plants and animals found in the Earth's crust and contain carbon and hydrogen
GHG	Greenhouse gas
Green technology	A description to use of technology and science to create products that are more environmentally friendly
HVAC	Heat, Ventilation and Air Condition
HVO	Hydrotreated Vegetable Oil
IGF Code	International Code of safety for Ships using Gases or Low-flashpoints Fuels
IMO	International Maritime Organization (by United Nations)
Marine Engineer	A person with competence certificate/ licence according to STCW
NMA	Norwegian Maritime Administration
SECA	Sulphur Emission Control Area
Special areas	Areas provided by IMO with a higher level of protection than other areas
STCW	Standard of Training of Certified Watchkeepers
Zero emission	Non-man-made greenhouse gas emissions shall reach the atmosphere from generating power to propulsion and auxiliary

10 Reference list

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11 List of tables and figures

Figure 1 The Diamond of Innovation

Table 1 Number of valid M1 certificates and age groups. Made by author.

Table 2 Overview over the interviewees. Made by author.