CHALMERS
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Designing Digital Learning for Maritime Communication:

A Framework for Asynchronous Instructional Tool Development.

Master's thesis in Master Programme Learning and Leadership

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DEPARTMENT OF COMMUNICATION AND LEARNING IN SCIENCE

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Abstract

Human failure accounts for approximately 70 % of maritime accidents, with routine ship-to-shore communication frequently deviating from standardized international safety protocols. While required operational competencies are highly standardized by international regulations, a lack in research exists regarding how these communication skills can be effectively taught and maintained through the use of modern digital solutions. Conducted as part of the Chalmers D-SMART project, this thesis addresses this gap by investigating the core research question: "What might a framework look like for development of digital learning tools for Maritime Communication?". The study utilized a qualitative research design, gathering data through semi-structured interviews with maritime and Vessel Traffic Services (VTS) educators and operators. This empirical foundation was iteratively coded and analyzed alongside a qualitative literature review of 18 peer-reviewed articles screened via a PRISMA-adapted framework. The synthesized findings resulted in the development of the Maritime Communication Learning (MCL) framework, which organizes operational design insights into three core pillars: Determining Learning Content, Choice of Learning Approach, and Wider Design and Development Considerations. By incorporating cognitive principles, such as the Cognitive Theory for Multimedia Learning and Cognitive Load Theory into software design choices, the framework balances pedagogical rigor with technical constraints. The MCL framework functions as a practical guide for engineers, developers, or educators to design, implement, and evaluate asynchronous digital learning environments that enhance long-term skill retention and promote global maritime safety.

maritime communication, instructional design, multimedia learning, learning frameworks, Vessel Traffic Services (VTS), digital learning tools.

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Max Fransson, Gothenburg, May 2026

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

4C/ID	Four-Component Instructional Design
ADDIE	Analysis, Design, Develop, Implement, Evaluate
AI	Artificial Intelligence
CBT	Computer-Based Training
CLT	Cognitive Load Theory
COC	Certificates of Competence
CRM	Crew Resource Management
CTA	Cognitive Task Analysis
CTML	Cognitive Theory for Multimedia Learning
ECLIPSE	Mnemonic search framework used for operationalizing queries
ERIC	Education Resources Information Center
EU	European Union
GMDSS	Global Maritime Distress and Safety System
GOC	General Operator Certificate
HOTS	Higher Order Thinking Skills
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IMO	International Maritime Organization
INS	Information Service
IxD	Interaction Design
MCL	Maritime Communication Learning
ME	Maritime English
NAS	Navigational Assistance Service
PBL	Project Based Learning
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
ROC	Restricted Operator Certificate
SAM	Successive Approximation Model
SLIM	Specifying Learner need in an Iterative Manner
SMCP	Standard Marine Communication Phrases
SOLAS	Safety of Life at Sea
STD	Self-Determination Theory
TOS	Traffic Organization Service

UI	User Interface
UX	User Experience
VR	Virtual Reality
VTS	Vessel Traffic Services

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1 Introduction and Background

1.1 Background

Seafaring has never been a safe endeavor; throughout the 20th century, several large ship disasters occurred, from the Titanic to more recent ones such as the Estonia catastrophe. Incidents such as these have acted as catalysts for technological advancements, modernized safety standards and guidelines which have greatly decreased the risk of accidents. There are however still issues within these advancements most of which are connected to us humans. According to Maternová *et al*, nearly 70 percent of maritime accidents between the years 2015 and 2022 can be traced back to human failures, often stemming from cognitive, perceptual or psycho-behavioral processes [2]. One of the avenues in which human failures occur is maritime communication where routine ship-to-shore communication has been shown to significantly deviate from existing standard protocols, according to a recent study by Jurkovič [3].

An EU-funded project named DigiMar was initiated by Jurkovič in 2023, partnering with several government agencies and institutions in higher education [4]. The main objective of the DigiMar project has been to enhance navigational safety, through changes in maritime communication skills in shore service operators and higher education students by implementing a digital educational pilot [5]. This pilot consists of educational material in the form of instructional videos, recorded real world maritime communication scenarios, as well as an AI-chatbot with the goal of supporting self-directed and continuous learning. The DigiMar project also states other project objectives such as to develop learner centered and needs based teaching practices, supporting new forms of interdisciplinary cooperation in higher education and developing the digital competencies of the target group users [6].
Chalmers University has initiated a project in collaboration with Swedish Maritime Administration (Sjöfartsverket) and the Norwegian Coastal Administration (Kystverket), named D-SMART. The D-SMART project builds upon some of the results from the DigiMar project and aims to create a digital learning platform which "integrates research-based teaching materials into maritime education and training at Chalmers and internationally". In these endeavors the project aims to contribute to the advance in research for increased safe and effective maritime communication.

This thesis, carried out as part of the D-SMART project, aims to support their mentioned project goals by injecting knowledge from traditional teaching and digital competence viewpoints. Teaching efforts require adaption depending on a multitude of factors such as the specific subject matter, situational context and individual learner backgrounds. In this study, maritime communication serves as a highly specialized domain defined by the intersection of language, technical communication, and human factors. When people interact with interfaces which are constrained by design choices, software, usability standards and technical competency, an additional dimension is introduced for how learning can be effectively promoted.

1.1.1 Problem Statement and Research Gap

While international governing bodies provide extensive, regulated standardization regarding what competencies maritime professionals and Vessel Traffic Services (VTS) operators must possess, there is a lack in scientific research addressing how these skills are effectively taught, developed, and maintained. This educational challenge is amplified by two research gaps:

Instructional Design mismatch: When digital tools are introduced to modern maritime education, development teams frequently prioritize software usability, User Interface (UI) design, or general User Experience (UX) over instructional systems design. Without grounding digital learning tools in verified learning theories, these systems risk inducing cognitive overload or failing to engage users psychologically [7, 8]. Existing materials sometime rely on passive multimedia formats, such as AI-narrated slideshow videos, which suffer from a lack of user interactivity and fail to foster the higher-order thinking skills (HOTS) required to handle highly volatile, real maritime scenarios [9, 10].

Continuous Learning: Maritime education often fail to support lifelong knowledge retention once a student leaves a university environment or completes certification. For employed professionals like VTS operators, formal refresher courses are held at infrequent intervals of four to five years. Empirical data from this report reveals that without systematic, workplace integrated follow-up, competencies fade rapidly, essentially returning operators to "square one" after refresh courses.

Consequently, a gap exists between standard regulatory communication requirements and the digital pedagogical frameworks needed to deliver them effectively. To prevent detrimental instructional design choices and ensure long-term skill retention, there is a need for an adaptable, structurally sound framework that bridges the divide between maritime standards, cognitive learning science, and digital tool development.

1.2 Aim and Research Question

The aim of this thesis is to bridge the gap between standardized maritime requirements and digital learning design by developing a conceptual learning framework for asynchronous digital environments. The study produces empirical field knowledge with established cognitive science to support the goals of the D-SMART project. By translating complex instructional system design principles into actionable technical recommendations, the framework seeks to guide interdisciplinary development teams in creating interactive tools that enhance long-term skill retention, manage cognitive load, and cultivate the higher-order thinking skills required to increase navigational safety. To achieve this aim this study addresses the following **research question:**

- What might a framework look like for development of digital learning tools for Maritime Communication?

1.3 Significance

The significance of this study lies in its capacity to translate data into practical design guidelines for digital education within a highly specialized, risk-prone industry. Several key stakeholders stand to benefit from the insights and frameworks generated by this research:

- The D-SMART research group can directly use these results to refine their digital educational pilots and ongoing digital platform implementations.
- Software developers, instructional designers, and educational creators can use this work as a blueprint when building or evaluating e-learning systems for maritime environments.
- Chalmers University of Technology benefits from the integration of interdisciplinary knowledge between traditional teaching and engineering-centric digital competencies.
- Future scientific studies within learning theory, maritime communication and multimedia design can use this thesis as a foundational link in the research chain to further explore technology-enhanced vocational training.

If the aims of the study are fulfilled successfully the results can hopefully have a positive effect on maritime safety and thus also bring a positive societal impact.

1.4 Scope and Delimitations

The framework is based on the specific types of maritime communication covered in the existing educational material and within the D-SMART project. This involves mainly ship-to-ship and ship-to-shore communication and will for example not deal with on board communication.

Additionally, the target audience for the framework can be divided into two groups:

- The first group consists of the designers and creators of digital learning tools. Within the context of this project, this specifically targets future members of the D-SMART project group at Chalmers, including Bachelor, Master, and potentially PhD students with engineering backgrounds.
- The second group are the end-users, consumers, and students who use the resulting digital learning tools. The student group is mainly university level and vocational students.

1.5 Key Concepts and Definitions

Learning framework - An organized structure with principles and rules that guide how education is effectively delivered, absorbed, and applied. It can work as a bridge that translates complex learning theories into concrete design and evaluation approaches. There are many different types of learning frameworks, Travers et al [11] present four aspects which can be used to categorize them:

1. The **Source** of the framework, who designed it.
2. What **Purpose** the framework serves, why it was created.
3. **Targeted learning or competencies addressed** in the framework. It could for example address prior learning, knowledge gained within an educational program or learning and knowledge accumulated over time.
4. With what **Intention** the framework was created. This could for example be formulating what skills and knowledge expected to be learned going through a specific learning experience.

Maritime communication - A broad field encompassing a wide range of information exchange at sea. To ensure global safety and consistency, it is governed by extensive regulations and guidelines standardized by international organizations. These frameworks cover both the operational procedures for specific scenarios and the technical standards for the equipment used.
In the context of this report, "maritime communication" refers primarily to interactions occurring **vessel-to-vessel** or between **vessels and shore-based stations**; it specifically excludes internal, on-board communication procedures and systems which are generally included.

Maritime English (ME) - A specialized and standardized form of English used globally by seafarers when communicating. Its purpose is to standardize communication, decrease misunderstandings and increase safety.
Standard Marine Communication Phrases (SMCP) - An official compendium of standardized safety-related phrases developed and regulated by the International Maritime Organization (IMO) [12].
Vessel Traffic Services (VTS) - Shore-side traffic management systems in vessel-to-shore communication implemented by regional authorities to monitor and manage vessel traffic in high-density or high-risk maritime areas. These operate under the regulation guidance from the SOLAS (Safety of Life At Sea) framework and guidelines from the International Organization for Marine Aids to Navigation (IALA) [13, 14].

1.6 Thesis Outline

The remainder of this thesis is organized into six primary chapters:

- **Chapter 2 Methodology:** Outlines the three-phase research design, detailing the implementation of expert semi-structured interviews, the execution of a qualitative literature review, and the subsequent thematic analysis.
- **Chapter 3 Results from the Studies:** Presents the findings gathered from the studies, the thematic clusters derived from expert interviews alongside the categorized data from the literature review.
- **Chapter 4 Discussion and Framework Creation:** Integrates the results with established educational frameworks to justify the structural reasoning behind the framework.
- **Chapter 5 The Framework:** Introduces the Maritime Communication Learning (MCL) framework and details its operational use across three core pillars: learning content, learning approaches, and wider design considerations.
- **Chapter 6 Conclusions:** Summarizes the insights of the thesis, answers the research question, and highlights pedagogical and practical implications for future development projects.

2

Methodology

The project followed a structure which included three phases, first an initial orientation and planning phase, second a research phase and third a framework creation and consolidation phase. These phases were somewhat overlapping and were mainly used as an internal tool for planning and implementation. The phases were planned in detail when initiated.

2.1 Orientation Phase

The "orientation" phase included planning of the overarching strategy for the project and examined what was needed to answer the research question. Choices of important avenues to explore to form the foundation for creating a framework were made. It encompassed choosing suitable scientific methods, design resources and planning the overall project structure.

Much of the work involved knowledge acquisition from the D-SMART and DigiMar projects by examining existing material such as videos, articles, regulatory documents and discussions with other involved members. This partly informed the focus of the research studies while also acting as an initial evaluation of how a framework could be used. There were also three bachelor thesis projects concerning development of software for the D-SMART project initiated and run in parallel with this project. This required navigation as to where this project was situated in relation to these, to the broader D-SMART project and if any collaborations could be beneficial. The research question and this initial knowledge gathering pointed to needs which came to motivate the methodological approaches used in the project.

2.2 Research Phase

The research phase constituted the largest part of the project and included each of the studies whose results formed the scientific foundation for the research. Included studies are mainly a set of expert interviews alongside a qualitative literature review. Evaluation of some existing material from the D-SMART project was also included.

2.2.1 Evaluation of Existing Materials

The orientation phase identified some existing educational material and relevant documentation for maritime communication which had been collected by the D-SMART project. These were evaluated to guide upcoming studies and to exemplify what online learning for the subject could look like. It informed what information to consider when creating learning for the subject of maritime communication and was used as one of the inputs in the framework creation phase.

2.2.2 Interviews

The interviews were performed using a semi structured format, recommended by Esaiasson [15] for interviewing subject experts, as they hold much of the knowledge regarding what is important to cover in an interview. The choice of interviewing experts partly stemmed from a need for complementary input on learning and maritime communication to a literature study. There also existed a need to be source critical of information from experts, highlighted by Kvale [16], which made literature study complement the interviews by acting as a separate source.

2.2.2.1 Interview Participants

Three interview participants with somewhat varying expertise but much common knowledge within the field of maritime communication were chosen. The first participant is a marine lecturer in nautical studies and at Chalmers School of Maritime Studies, also in charge of the Undergraduate program for Master Mariner, with many years of practical experience. The second participant is an experienced VTS-operator at Sjöfartsverket (Swedish Maritime Administration) with around 15 years of experience as an operator, practical experience as a Master Mariner and now also involved in education of VTS-operators. The third participant is a VTS-operator and instructor at Kystverket (Norwegian Coastal Administration) with a background working within the Norwegian coast guard, VTS-operator and is the main instructor for introductory and reoccurring VTS-operator courses for all operators in Norway.
The aspiration was to create good coverage while simultaneously having multiple input sources for central maritime communication information.

2.2.2.2 Planning, Designing and Booking Interviews

When designing the interview structure, an interview guide was created, based on recommendations from Kvale [16] and Esaiasson [15], with a clear structure for each interview to follow. The planning also involved determining aspects surrounding the interviews, where and when they should be held, if the guide should be adapted between interviews et cetera. It also involved determining how the data would be handled and analyzed after the interviews. The intention behind determining such details was to the extent possible create an interview where focus could be placed on the important aspects of gathering relevant data. The interview guide was somewhat edited in between interviews based on interesting topics raised during the initial interviews. The entire guide, (In Swedish), can be viewed in appendix B.

Contracts for how personal information was handled were written to be signed by interviewees before their respective interviews. The contracts included information on how recorded interviews were to be handled, stored and transcribed. The contract followed Chalmers general handling of personal information. These contracts were also written to inform the participants of the overall purpose of the study and their part in it. The interview recordings and transcriptions were saved locally for the duration of the project, up to a maximum time of six months.

2.2.2.3 Holding Interviews

Each of the interviews were held online via Microsoft teams as none of the interviewees were available for on site interviews. Recordings were made with the platforms built in audio recording software.

As per the created guide the interviews were initiated by informing the participants of the format and a reminder of the purpose for the interview. Following this were a few warm up questions where the interviewees were asked to share their background and relation to the subject of maritime communication. These initial parts had the intention to set expectations, make the participants feel more comfortable and encourage participation, as recommended by both Kvale [16] and Esaiasson [15].
The interviews then consisted of asking the participants open, 'grand tour' questions, covering four themes chosen based on information gathered during the orientation phase. The 'grand tour' questions served as the primary entry points for each interview, obtaining broad responses which promoted subsequent inquiry. The four themes were:

1. Maritime communication knowledge and skills
2. Learning methodology
3. Target groups
4. Technical and digital aids

Most follow-up questions were adapted organically to the evolution of the participant's narrative, while others were intentionally guided by pre-determined sub-themes or specific requests for clarification. Once discourse surrounding a topic had been discussed and the interviewee had nothing to add, the interviewer asked direct questions to address specific research interests. These for example included asking their views on the existing educational material which they knew of and had used.

2.2.2.4 Transcribing

Interviews were transcribed utilizing the Chalmers AI portal. The transcriptions were then verified to be correct by listening through each interview while reading the transcription and making manual corrections where there were errors. This method facilitated an efficient workflow without compromising analytical quality. Given that the necessity of capturing specific speech nuances depends on the research context [16], it was concluded that the transcripts retained sufficient detail, with no substantial loss of information.

2.2.2.5 Thematic Analysis

Thematic analysis was conducted by systematically reviewing each transcript and deductively assigning one or more codes to relevant data segments. Following the recommendations of Gibbs [17] for analyzing qualitative data, the coding strategy prioritized analytical and categorical labels over purely descriptive ones. Open coding was the main approach used alongside some additional methods from grounded theory. This process was facilitated by the qualitative analysis software, Taguette [18], where each code was assigned a label , creation date, and accompanying analytical memos. The coding process was iterative in that the generated codes were repeatedly reviewed to ensure that the data segments aligned with their assigned labels. This included gathering text segments with specific codes and analyzing if there was any core concepts linking them. If discrepancies were identified, codes were either refined, renamed, or restructured. The final codes were then tagged with a concept level marker and grouped into a hierarchy of categories and subcategories, with each level supported by illustrative quotes to ensure the analysis remained grounded in the data. The main sections in the result chapter for the interviews represent the top level of this categorization.

2.2.3 Literature Review

The literature review followed a systematic approach adapted from the PRISMA 2020 guidelines [19]. While this study did not aim to produce a full-scale systematic review, the PRISMA framework was employed to ensure methodological transparency, replicability, and rigor throughout the identification and screening phases.

The search and analysis consisted of two parts: an iterative search and screening process, followed by a thematic analysis. The search strategy was executed in two iterations, where the initial search was informed by the orientation phase, early interviews and a preliminary scoping review. The second iteration had a more targeted approach, incorporating insights from both the initial search and the analysis of the interview data.

2.2.3.1 Identification and Search Strategy

The literature search was conducted across two academic databases selected for their relevance to the research objectives:

- **Scopus:** Selected for its extensive multidisciplinary coverage of peer-reviewed literature, providing a broad foundation for the review.

- **ERIC (Education Resources Information Center):** Utilized for its specialized collection of high-quality education and social science research, curated by the U.S. Department of Education.

In the identification phase, the research questions were operationalized into search strings for execution across selected databases, examples of these are presented below. The entire set of search strings used can be found in appendix A. The search strategy focused based on initial results from the interviews, and queries were developed using the ECLIPSE framework [20].

ERIC Database example

```
(simulators OR gamification) AND (communication) AND (Learning
OR Training) AND (online-learning OR Digital-learning)
```

Scopus Database example

```
TITLE-ABS-KEY((simulators) AND (communication) AND (Learning OR
Training OR Teaching) AND (Aviation OR Maritime OR Marine)) AND
(LIMIT-TO (LANGUAGE, "English")) AND PUBYEAR > 2006 AND PUBYEAR
< 2026
```

2.2.3.2 Screening and Selection

To further delineate the scope of the review, explicit inclusion and exclusion criteria were created, as summarized in Table 2.1.

Table 2.1: Inclusion and Exclusion Criteria for the Literature Review

Category	**Inclusion Criteria**	**Exclusion Criteria**	**Rationale**
Publication Date	2006–2026	Before 2006	To reflect a more current technological context.
Language	English	Other languages	Linguistic constraints of the researcher.
Publication Type	Peer-reviewed articles, Conference proceedings	Books, Editorials	Focus on validated, primary research findings.
Topic Scope	Focused on specific research theme	Focused on out-of-scope topics	Maintain alignment with research objectives.
Access	Full-text available	Restricted/Paid access	Ensure feasibility.

Search results were exported to Rayyan, a systematic review screening tool, to assist the management and analysis process [21]. The software's AI functionality was utilized to identify and remove duplicate records.
The screening process was conducted in three stages:

- **Initial Screening:** Title and abstract review.
- **Secondary Screening:** Review of introductions and conclusions.
- **Full-text Assessment:** Comprehensive review of the remaining records.

Throughout this process, notes regarding the content of the records were systematically documented to support the subsequent analysis. An overview of the process is presented in the PRISMA diagram in figure 2.1.

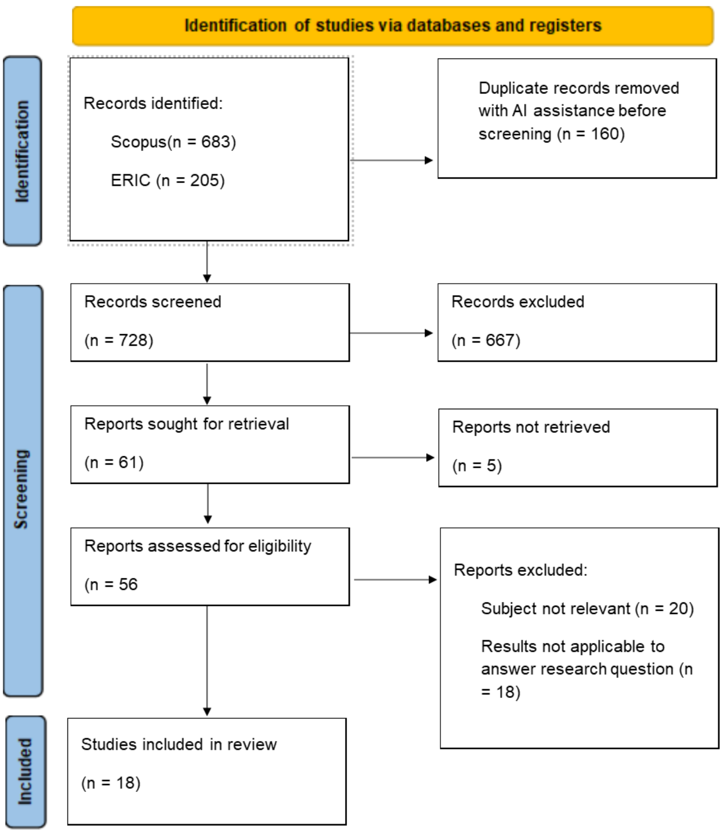

Figure 2.1: PRISMA flow diagram

2.2.3.3 Analysis

After each record had been assessed for inclusion, a thematic analysis was performed where notes for each included article was summarized and annotated. Summaries were then categorized by themes relevant for framework creation and tagged with their source of origin. These themes relevance was partly inspired by the thematic coding of the interviews, as well as from initial ideas surrounding framework content developed during the orientation phase.

2.3 Framework Creation Phase

The framework creation process involved evaluating the results of the studies and combining conclusions drawn from these with other relevant theoretical sources, some inspired by the findings. Summaries were created of relevant parts of these theoretical sources, such as books on Instructional Design, maritime documentation and other scientific literature. The implications of these summaries and the results in conjunction are discussed in section 4. By then guiding discussion and design reasoning by defining categories, as presented by Travers et al [11], the aspects most relevant were combined into a framework. Since the framework is intended as a practical tool mainly straight forward directly applicable principles or design suggestions were included.

2.4 Writing

The thesis was written using LaTeX. Several of the figures used were designed using Canva [22] and some of the formatting of the tables was creates using Google Gemini [23]. Gemini was also used to proofread this report and sometimes asked for suggested formatting of unclear sentence structures.

3

Results from the studies

This chapter covers the results from both of the main studies, the interviews and the literature study. It also includes some relevant information from the early evaluation of the preexisting educational material used by the D-SMART project.

3.1 Initial Evaluation Summary

Existing educational materials in the D-SMART project included 20 basic instructional videos for Routine maritime communication for VTS and nine videos covering different VTS-scenarios as well as documentation from the International Association of Marine Aids (IALA), the International Maritime Organization (IMO) Standard Marine Communication Phrases (SMCP) as well as some scientific articles on maritime communication.

The basic videos were 2-6 minutes long and partitioned into four categories.

1. Background and context, three videos.
2. VTS-phraseology, two videos.
3. Clarity of speech, 11 videos.
4. Ambiguity, four videos.

The videos covering different scenarios involved five videos based on accident report and four based on case studies of authentic situations. The videos mainly use AI-based narration combined with supporting text in a slideshow format. The voices are clearly heard and present information at a slow pace.

3.2 Interviews

Thematic analysis of the interviews resulted in five topic areas each with several sub clusters of topics. An overview of these themes is presented in figure 3.1. Quotes from the interviews are presented to anchor the results in the research data and for transparency. [1]

[1] "All interview quotes were translated from Swedish to English by the author."

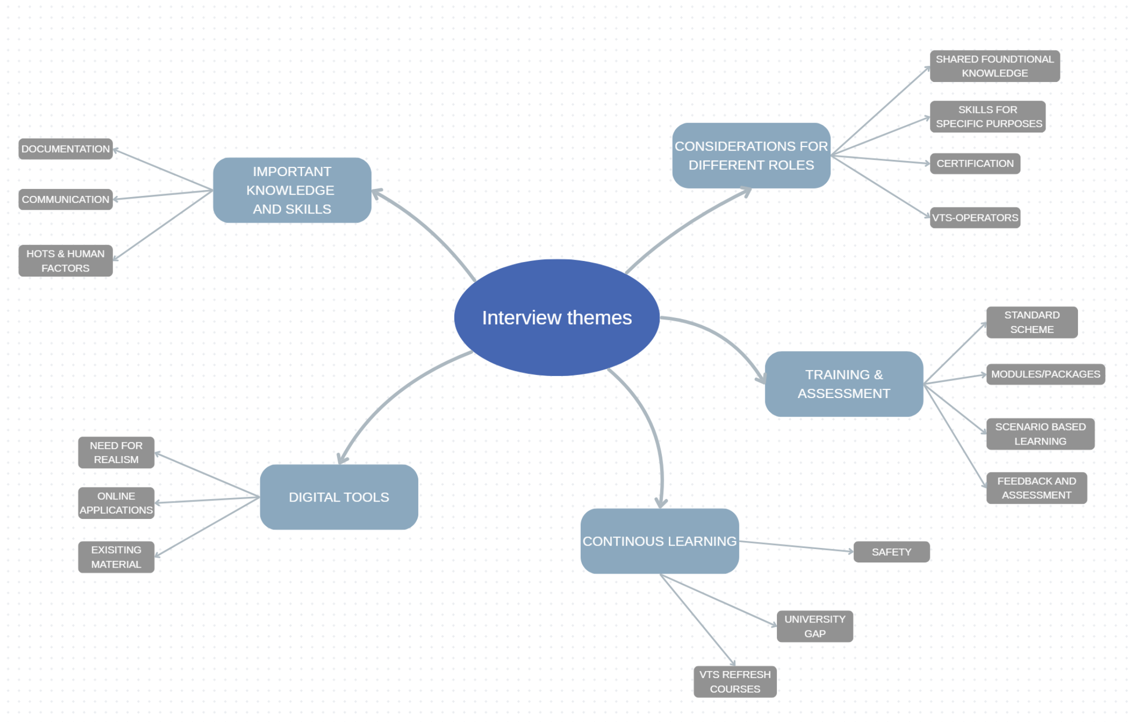

Figure 3.1: Interview themes

3.2.1 Important Knowledge and Skills

Several dimensions regarding what knowledge and skills were seen as important for maritime communication were provided by the interviewees. The categories are Documentation, Communication, Higher Order skills and human factors.

3.2.1.1 Documentation

Much of the basic skills and knowledge mentioned in the interviews connected to specific governing documents for maritime communication. The IALA guidelines [14] and IALA course guide modules C0103 were mentioned as main sources of relevant competencies for VTS as well as other areas of maritime studies.

> **VTS-operator educator:** "We very much lean against that IALA guide which is the guide for VTS-communication."

It is also mentioned that these guidelines are somewhat up for interpretation. The IMO SMCP [12] is referenced as a main source for guiding vocabulary use.

3.2.1.2 Communication

Interviewees mentioned several explicit communication aspects they deem important. These included:

- General English competency
- Maritime English (ME) proficiency specifically

- Listening skills
- Ensuring your communication is understood
- Radio usage
- Being concise

These were especially important in VTS communication. Nonverbal aspects or nuances in how one speaks was also advocated for, tonality and clarity contributing to sounding trustworthy and professional were mentioned.

> **VTS-operator:** "Hearing the nuances of language. I mean, there are people who just can't hear nuances in speech "

> **Master Mariner educator:** "I mean, the importance of sounding professional on the radio—it's really the only way for you to signal your competence to other boats."

> **Master Mariner educator:** "The baseline is understanding the radio, understanding its limitations. Understanding the different channels, switching between them, calling someone, answering someone."

General maritime English can according to interviewees both be a benefit and sometimes a detriment. Since Maritime English specifically for VTS is a language adapted to be more terse and efficient than regular English, it can result in experienced speakers having a hard time adapting their usual way of speaking. At the same time with a breadth in their English it opens up possibilities for communicating a message in different ways.

> **Master Mariner educator:** "You can sit at a pub in England and talk to people, using a rich vocabulary and all that. But that's a dangerous trap."

> **VTS-operator:** "It's not that you need to speak advanced English, but you should be proficient enough to adapt your message and add nuance to it if the person doesn't understand. You should actually keep your language very simple.

3.2.1.3 Higher Order Skills and Human Factors

Additional competencies such as situational awareness, decision making, ability to adapt, visualizing scenarios or being able to handle stress and other emotional aspects were pointed to alongside the concrete communication skills.

VTS-operator educator: "One factor is about general situational awareness."

Interviewer: "In your opinion, which skills and knowledge are important?"
VTS-operator: "Interpreting an image or a conversation and translating it into a mental image, a situation, imagining how a situation will develop."

A reoccurring mention from the interviewees was that some of the important skills, usually higher order skills, are seen as more innate, personality dependent or at least harder to practice. Some examples were stress handling:

Master Mariner educator: "Some people are quiet, others are talkative. Uh, some are used to it and aren't self-conscious about speaking in front of people, like. Others are very shy. So there are huge differences in individual starting points."

VTS-operator: "We had a girl quite recently who—I mean, she she got super nervous as soon as she was supposed to pick up the handset and say something. So it just didn't work out, uh. So no matter how much she practiced, she she had a hard time."

Risk assessment is one of the main tools of a gauging how to approach and handle communication with other ships.

Master Mariner eductor: "I mean, you have to make a risk assessment based on the other boat's response. And that, that's what the VTS does too. ... then you really want to hear a confirmation that it's received. If that doesn't happen, or if you don't get it automatically, you start raising the risk on this boat."

One of the most important aspects is preparing to handle unknown, unique situations, but these are also the hardest to practice for.

VTS-operator: "One of the difficult things is when there are unique situations that the operators are unfamiliar with." "It's really tough, I mean you can practice high-pressure situations, but it has to be second nature. It's hard to verify that you, that you've practiced the right way until it happens—you don't know how, how you'll react until this weird situation arises. You don't get a second chance to, to fix it, so to speak."

3.2.2 Considerations for Different Roles

Roles such as VTS-operator, Master Mariner or Maritime officer have differences in their knowledge and skill requirements. The roles have different amounts of required education while also sharing much of the same foundational knowledge. VTS-operators in both Sweden and Norway are for example required education as a Master Mariner.

> **Interviewer:** "What training programs and such form the basis for your operators? You mentioned, it is primarily this Master Mariner training, as I understand it."
> **VTS-operator:** "That is the basic requirement for employment at the moment."

It was emphasized that differences between roles mainly involve honing general maritime communication skills for specific purposes rather than developing completely new skill sets.

> **Master Mariner educator:** "There really is no difference in the fundamental principles, whether you are talking to another boat or talking to VTS; there's really no difference, it is the same basic concepts that apply."

> **VTS-operator:** "VTS communication is just phrases within maritime communication that are used by VTS. But everything is based on maritime communication. VTS communication isn't its own thing; it *is* maritime communication."

There were also aspects highlighted of differing levels of certification for different roles which need to be taken into consideration. A General Operator Certificate (GOC) for GMDSS radio systems, is for example usually included in a master mariner education, while other roles and occupations may only require the more basic, Restricted Operator Certificate (ROC)-certification.

> **Master Mariner educator:** "The qualifications you need to work as—well, it ends up being a radio operator, but it's part of this deck officer role—are pretty strictly regulated. And these radio certificates, they're quite heavily controlled. ... there are two ship certifications that are important for you to understand. One is what's called **ROC**, which stands for *Restricted Operator Certificate*. ... The larger course, called **GOC**—the *General Operator Certificate*—basically allows you to act as a completely unrestricted operator."

3.2.2.1 VTS Operators

Some additional insight surrounding VTS-operators in particular was forthcoming. They are in contrast to maritime students at universities full time employees who require initial or complementary education. This usually in the form of initial on the job training or refresh courses for renewing licensees.

It was highlighted that there are certain maritime experience and knowledge that is especially import for VTS-operator. An example was coastal navigation.

> **VTS-operator:** "But it's clear that there's quite a big difference between someone who has been sailing in foreign trade for 2 years and someone who has been sailing, well, coastally for 2 years. And VTS is really about that, the coastal side of things. It's definitely an advantage to have varied experience among the operators regardless, but it's coastal navigation that it's actually about."

Additionally some maritime communication knowledge is more niche, such as message markers, required by VTS.

> **VTS-operator:** "I don't think I had heard of Message Markers before. I worked at sea for 15 years; I didn't hear about Message Markers until I started in the VTS industry."

Again, awareness of these role specific skills and knowledge when designing learning tools appeared useful.

3.2.3 Training & Assessment

The interviewees pointed to a somewhat standard scheme for teaching maritime communication which involves the reading of theory followed by practice in applying the theory, usually using simulator training. This is used both in a university setting and when educating VTS-operators.

> **VTS-operator educator:** "The refresher course is 3 days, and it's a mix of theoretical knowledge and a very large part is simulator training."

Within this overarching structure specific approaches were mentioned. The subject was for example usually partitioned into modules/packages for which iterations of theory followed by practical application is repeated.

> **Master Mariner educator:** "Now you know basic calling communication—it works like this. We have learned how to pass the ball back and forth, saying 'over' and that type of thing. So, we move on. Now we will do distress communication, involving these procedures, and then we apply that. Next, we test the radio, and we do it like this. You continue through a number of different 'packages' like that which are important."

VTS-operator educator: "We have the Information Service (INS), where we provide information. Then we have the Traffic Organization Service (TOS) and Navigational Assistance Service (NAS). We aim to go through all those themes, and finally, we have a 'mix-exercise' which includes simulations, where everything is integrated."

Use of real or realistically created scenarios, especially in simulator training was a reoccurring point.

VTS-operator educator: "Then there are simulator exercises where we have created scenarios intended to be realistic; that is, the simulator exercises are based on real-world events."

VTS-operator educator: "... additionally, I include many examples from my own communication where I have performed well or poorly; I play these back so they can provide comments and engage in some problem-solving."

Master Mariner educator: "Like I mentioned, it sounds more like—well, you want to get as close to a real simulation as possible, or perhaps closer to such scenarios."

This motivates trying to create or use realistic scenarios when creating learning.

Other interesting aspects for learning were brought up by the interviewees, such as the importance of constructive feedback, especially for simulator training and other scenario based training.

VTS-operator: "Yeah, it doesn't really help to point out what's wrong if you don't, if you don't get help on how to do it right."

Assessments is closely connected to feedback. It was brought up that assessments such as tests, usually involve high grade limits, especially before simulator training and is connected to certificates or regulations

Master Mariner educator: "So before each simulator session, they have to find quite a few documents in the regulations, read them, and then use them as a basis to answer a quiz. Then, they're actually required to get 100% correct on the quiz, so they have to redo it until they get 100% right."

Regarding assessment and feedback of VTS-operators there is feedback during the infrequent refresher courses. There was according to the VTS educator often too much focus by operators on the grade they're given, and not on the feedback for how they can improve.

> **VTS-operator educator:** "The grade itself isn't really that important. The grade is just there to see progress. But I find that the students get really hung up on what grade they get. You've passed, and when it's written down, it's maybe more about what you should take with you moving forward."

There was also feedback during annual assessments of VTS-operators, performed by colleagues.

> **VTS-operator educator:** "Once a year, there's something called an annual assessment. We're going to look at this this year,' and then you check how the employees are meeting those requirements, or if any measures are needed to help them meet them."

The interviewee raised some doubt about how honest these assessment are since giving feedback to a colleague can be sensitive and that the dynamic is different at explicitly educational meets.

> **VTS-operator educator:** "No, I see that it's hard to make work, I mean... it's one of your colleagues, right, who's going to sit there at work and say, 'No, don't say it like that, say it like this'... It's easier to be corrected by someone who is actually there to train you, you know?"

3.2.4 Continuous Learning

Maintaining skills and competencies was pointed to as important, it is the reason certification is required, especially in aspects impacting safety such as communication.

> **Master Mariner educator:** "There are a vast number of conventions that must be met, otherwise, they don't get their certificates... essentially, it is a safety matter."

After a university maritime education there are few requirements for keeping knowledge up to date. It is mainly up to independent employers such as shipping companies to determine requirements for any continuous learning of their maritime professionals.

Master Mariner educator: "Once they receive the certificate from me after passing all the examinations, then they go out to work. If they don't stop sailing —meaning they just continue at sea— I don't see them again for this. There is absolutely no knowledge follow-up whatsoever."

Master Mariner educator: "Some companies—and this isn't regulated—but many shipping lines have requirements from customers and others to give further training for their personnel. Because of this, they often use Computer-Based Training (CBT) modules. You could easily end up at a shipping company where you are required to complete such a CBT course in radio communication."

For operators the refresh courses are held at 4-5 year intervals during a couple of days and the interviewees mentioned that most of what is covered during these meetups are forgotten. Detailed feedback was also provided to the learners regarding their performance during a refresh course, but was however often disregarded and focus was placed to much on just grades, they returned to old habits quickly. Indicating that continuous work place follow up is important.

VTS-operator: "All operators have to take a refresher course. Yeah, a maximum of 5 years in between."

VTS-operator educator: "As long as the training isn't followed up at the workplace, much of it is wasted. You're saying that when you return after four years, it's essentially back to square one again."

3.2.5 Use of Digital Tools

The interviewees were also asked about what they think of using digital tools in learning and specifically what they think about the existing video material in the D-SMART project, which they were familiar with.

One of the participants point to the importance of realism in scenario based training online by not giving VTS-operator too much graphical information about a scenario. In practice they receive much of the information via text and other sources. By providing learner with too much illustrative material it could hamper their development of visualization skills for instance.

VTS-operator educator: "The scenarios were structured more with illustrations of what the coast actually looks like, instead of just trying to piece it together, but it was the nautical chart that was used there—the vessels were placed with a vector so you could see where they were heading.

Uh, it's easier to understand the situation than when you start reading a piece of paper about 'that vessel, that course, and that speed.' If you see it on a nautical chart with vectors, you recognize it instantly—you see the situation right away."
Interviewer : "No, but you don't get that kind of overview in real life."
VTS-operator educator: "No, you have to start reading text and then, like, form a mental picture in your head of how the coast..."

The Master Mariner educator discussed some possible uses for online tools.

Master Mariner educator: " Cramming vocabulary, for example, just having the computer ask, 'Uh, what does this word mean?' Or, 'Say this word,' or express this in some way. You get a course. You get a position, you get a speed. You get something that is, that is strictly standardized—you know, these kinds of things. And then you just have to say it right, and the computer checks it. That... it becomes very simple to do something like that. It's incredibly valuable."

Another suggestion using voice recording was suggested.

VTS-operator: "Yeah. Yeah, but it could be that you record yourself and then listen to your answer, and then, and then maybe you get, uh, let's say questions about this. How, how would you perceive yourself? I mean, are you clear? Are you?"

One of the interviews pointed to a lack of interactivity in the preexisting video material.

VTS-operator: "It just becomes, it's just a video you w-watch, so to speak. You, you're not really interacting with the information."

3.3 Literature

The literature study includes 18 articles and a set of themes developed via qualitative analysis. An overview of the articles included, sorted by author, is presented in Table 3.1. The thematic analysis resulted in categorization into four main areas. These are *Target groups and Learner profiles*, *Ways of learning*, *Simulators* and *Design*. Table 3.2. gives an overview of the mapping between the articles and themes.

Author (Year)	Title
Abspoel, L. et al. (2021) [24]	Communicating Maritime Spatial Planning: The MSP Challenge approach
Balderas, A. & Losey-León, M.-A. (2018) [25]	Virtual learning tool for the training of the standard marine communication phrases
Bjørn, P. et al. (2024) [26]	Social fidelity in cooperative virtual reality maritime training
Elhakim, A. (2025) [27]	Conceptualizing Academics Experiences in Adopting Project-Based Learning in Maritime Higher Education: An Analysis through Activity Theory
Ferreira, A. (2017) [28]	Creating a maritime English board game to facilitate the memorization of specialized vocabulary
Guo, X. et al. (2026) [29]	Enhancing Maritime Safety Through Needs Analysis: Identifying Critical English Communication Skills for Pre-Service Maritime Students in a Chinese University
Harrington, S. (2024) [7]	Enhancing Scenario Design in Maritime Education and Training
Jamil, M. G. & Bhuiyan, Z. (2021) [9]	Deep Learning Elements in Maritime Simulation Programmes: A Pedagogical Exploration of Learner Experiences
Janssen, T. et al. (2023) [30]	From Ship to Shore – Studies Into Potential Practical Consequences of Autonomous Shipping on VTS Operation and Training
Jurkovič, V. (2025) [31]	Routine Maritime Communication At Higher Education Institutions Along The Eastern Adriatic Sea
Kudryavtseva, V. et al. (2021) [32]	Active Learning Strategies In Maritime English Training
Kudryavtseva, V. et al. (2023) [10]	Promoting Active Online Interaction with Maritime English Students
Mansson, J. T. et al. (2017) [33]	Joint Activity in the Maritime Traffic System: Perceptions of Ship Masters, Maritime Pilots, Tug Masters, and Vessel Traffic Service Operators
Moon, J. N. J. & Tudhope, D. S. (2006) [34]	An agent-directed marine navigation simulator
Sadowski, J. & Stefanski, J. (2024) [35]	Hybrid Laboratory of Radio Communication with Online Simulators and Remote Access
Sari, D. W. et al. (2025) [36]	Polimarlish.id, a game-based learning website to meet the standard marine communication phrases proficiency
Verstegen, D. M. L. et al. (2009) [8]	Designing Needs Statements in a Systematic Iterative Way
Wang, Y. (2025) [37]	An Empirical Study on the Blended Learning of Maritime English Based On Desktop Virtual Reality Technology

Table 3.1: Collection of included articles

Theme	Sources
Target Groups and Learner profiles	Guo (2026); Mansson (2017); Verstegen (2009)
Ways of learning	Balderas (2018); Elhakim (2025); Ferreira (2017); Guo (2026); Jamil (2021); Janssen (2023); Jurkovic (2025); Kudryavtseva (2021); Kudryavtseva (2023) ; Mansson (2017);
Simulators	Abspoel (2021); Bjørn (2024); Harrington (2024); Jamil (2021); Janssen (2023); Kudryavtseva (2021); Moon (2006); Sadowski (2024); Wang (2025)
Design	Harrington (2024); Moon (2006); Sadowski (2024); Sari (2025); Verstegen (2009)

Table 3.2: Literature Review: Themes and Sources

3.3.0.1 Target Groups and Learner Profiles

Effective learning in general requires understanding of differing learner needs, which can vary based on experience, motivation and objectives. In a study involving 313 students Guo et al. [29] identified two distinct learner profiles within Maritime English (ME) education through the lenses of Self-Determination Theory (STD) and principles for Crew Resource Management (CRM).

- **Exam-focused Learners:** Characterized by high external motivation such as passing grades. These learners, typically in lower grade levels, prioritize skills required for tests and use passive learning activities with a focus on the specific skills and knowledge involved in examination.
- **Work-focused Learners:** Driven by career goals, usually later year students, with an awareness of practical applications of their knowledge and relevant skills to focus on. They are more proactive in their learning, internally motivated and keen to achieve a long term competency.

The study also examines and evaluates the deemed importance of 84 different skills within Maritime English. Among 24 ME skills identified as statistically significant by Guo et al. based on the learners own evaluations of skill importance. Some skills present as more important for Exam-focused learners, some for Work-focused learners and some important independent of profile.

For basic learners these involve basic VHF-radio competency and terminology, translation and reading. Highly demanded for Work-based learners are instead skills such as VTS-response and distress transmissions, cross cultural communication and several aspects regarding on board communication. Common important skills for both profiles include seven skills in safety and security, with goals to meet industry requirements, and proficiency in SMCP application in line with IMO standards.

Beyond student profiles, Mansson et al [33] highlight that English competency is used between ship-side personnel and VTS operators as a proxy to determine professional competency. This is accompanied by showing stark differences in communication attitudes with different on board roles. This might indicate a need for learning tools to include interpersonal and role specific demands of the Maritime Traffic System. Verstegen et al. [8] mention taking the differences in learner profiles into account when designing learning tools as important.

3.3.0.2 Ways of Learning

Several different approaches for teaching Maritime communication emerged.
For Maritime English Jurkovic [31] observes a traditional approach involving instruction, followed by practice tasks such scenario based role play. These approaches, often used in practice do sometimes differ somewhat from methods found in syllabi for ME, where for example pair work, dialogues and role play are suggested [31].

Deep learning skills, and fostering Higher Order Thinking Skills (HOTS) presents as important for Maritime Communication [9, 29, 32]. Deep learning includes such as critical thinking, problem solving and learning to learn while HOTS are defined as analyzing, evaluating and creating [38]. Jamil et al. [9] point to learning approaches with simulator training which can foster deep learning skills, presented in section 3.3.0.3. Using learning strategies where the learner is actively involved, which focus on HOTS and deep learning skills are recommended for teaching ME [32]. Other recommended strategies involve encouraging student reflection, either on their own performance, on course material or on learning strategies in order to personalize the study experience; Self assessment and correction to increase self-awareness and efficiency.

For online learning Kudryavtseva et al. [32] points to using a Flipped Classroom approach where students practice fundamental knowledge before coming to a lesson, where they then practice a structured analysis of maritime accident reports. This is mainly used for more experienced learners in later ME education. A recommendation is including questions and exercises in the preparatory work that then stimulate group discussions with others to reach HOTS.

Elhakim [27] highlights two differing perspectives on teaching maritime communication, between academics from a more traditional university background and faculty comprised of master mariners or marine engineers with maritime backgrounds, holding Certificates of Competence (COC). Those with academic backgrounds were to a higher extent proponents of developing HOTS and deep learning via more transformative methods, using for example Project Based Learning (PBL). Those with marine backgrounds instead put more weight on COC requirements with practical skills and competencies in focus. It appears important to find integration or at least clarity of design and user focus between these two viewpoints when creating learning tools.

The use of real communication scenarios for teaching Maritime Communication shows positive effects [31, 29]. In the case of ME with the purpose of helping align authentic communication with standards as well as exemplifying real world use. According to Guo et al. real world scenarios also help increase Exam-focused learners motivation while for Work-focused learners giving an opportunity to practice with more advanced scenarios [29].

The importance of a learner centered approach based on the target groups is a reoccurring theme [8, 9, 27, 29]. For Exam-focused learners, linking basic SMCP phrase memorization with real scenarios is recommended. Either using simulations or via case-based teaching, with simplified accident cases [29]. Ferreira [28] and Balderas [25] both exemplify some of these strategies in different settings. Some examples are:

1. Being given communication instructions based on a real scenario, and asked to translate these into maritime English.
2. Being asked to fill in intentionally left out gaps in communication scenarios. Either with choices or from memory.
3. Receiving information from a communication scenario and being asked to answer questions surrounding it.

Good **Feedback** is highlighted as especially important for these.

For Work-focused learners immersive simulation training, via for example virtual reality is proposed, alongside more collaborative, preferably cross-cultural or expert associated training.

Additional suggestions involve categorizing scenarios or exercises based on the the VTS intervention ladder provided by IMO for managing risk [30]. Dividing scenarios into different risk levels could open possibilities of tailoring learning depending on group or individual needs. Adaption of repetition needs with a Spaced Repetition algorithm, where repetition is adapted based on learner needs to achieve Spacing effect is exemplified by Balderas [25]. Long term memory retention is then boosted by repeating material in spaced intervals determined by the algorithm. Balderas [25] also presents use of flexible data structures, where in certain data, such as types of words or phrases are programmed to be interchangeable with one another. This creates the technical opportunity to create different versions of a single created format by changing the variable values. For example by changing a word in an exercise, where the exercise is to explain the meaning of a sentence, the meaning can be made variable by what words are chosen in specific places.

3.3.0.3 Simulators

Simulator training presents as a widely used educational tool within the maritime sector, with both on site simulator training and digital simulators incorporated. Real world maritime scenarios include high risk and dire consequences when mistakes occur. An important aspect when creating and using simulator training is therefore allowing for exploration, experimentation and risk taking, to create opportunities for deep learning [9]. Anchoring simulator training in competency requirements (IMO) and technical standards (ISO) for simulators should be considered [9].

Adaption to learner groups and connecting to real world scenarios are important in simulator learning as well. Additionally simulator scenarios increasingly benefit from an high degree of similarity to the simulated real world situation, to the extent possible [9, 10]. Some aspects can however be hard to implement in a simulator settings, awareness of these is then needed and how they can be covered elsewhere.

A flipped classroom with modules created to prepare before simulator practice -similarly to the preparation before group discussions mentioned by Kudryavtseva [32]- which allows for implementing more challenging simulations [9]. A lack of preparation before simulator sessions is reported, especially from externally motivated students, the preparatory work therefore has to be designed with this in mind.

Some specific types of simulators can be found; bridge simulators are used extensively in maritime education and they present opportunities for practicing communication aspects along with many other skills in tandem. They are often complex, realistic and have high requirements for implementation. Wang et al. [37] point to low immersion, or screen based virtual reality bridge simulators as an option to increase realism when practicing scenarios in an online setting. The complexity allow for practicing deep knowledge via so called Knowledge-based teaching [37]. Sadowski [35] shows examples of online simulators with graphical interfaces, which increase realism, and how these can be integrated into an e-learning context.

Technical challenges and aspects to consider when developing simulators are also exemplified [34, 35]. Moon et al. show how realism can be increased by using an object oriented approach to create independent self operating simulator agents. These can be used to create different scenarios for simulations which require adaption by the user. Bjorn et al. [26] highlight the use of simulators as especially important when practicing for real world scenarios which involve a high tempo and a need for speedy decisions. They also point to the importance of Situated Learning positing that knowledge is best acquired within the context or environment it is used.

Abspoel et al. [24] present a simulator version of a board game, created to generate internal motivation. Their simulation game is mainly for planning and decision making, although dealing with more logistical and navigational aspects than purely communication related. They highlight a risk of using games in simulator settings: if the distinction between fact and fiction is too blurred, users may view the games as entertainment and dismiss any real-world value.

Sari et al. [36] present a game-based learning website, polimarlish.id, for maritime communication, especially for practicing communication phrases. The Gamification aspect involves receiving scores for completing exercises, with better scores awarding more points. Exercises included such as matching words or pictures, matching sounds, jumbled words or fill in the blank. They stipulate based on user feedback that the website was an effective tool to increase motivation in learners by providing a more fun way to practice maritime phrases [36].

3.3.0.4 Design

When designing digital learning tools, collaboration between Instructional Designers to guide how to optimize learning and subject experts has a strong effect on creating useful tools according to Verstegen et al. [8].

Harrington et al. [7] point to the importance of following an Instructional Design model when developing learning tools and that there are many option such as the broadly used ADDIE (Analysis, Design, Develop, Implement, Evaluate) method. They also illustrate the use of an alternative Instructional Design model, developed for training complex skills, named Four-Component Instructional Design model (4C/ID) [39] which they apply specifically towards development of simulation scenarios. Verstegen et al. [8] also present an Instructional Design model, which they created, named SLIM (Specifying Learner need in an Iterative Manner) to be used during the initial phase of developing especially complex learning tools, such as simulators. It includes six principles:

1. Design based on learning needs.
2. Design systematically.
3. Design iteratively.
4. Manage uncertainty through explicit assumptions.
5. Reuse information.
6. Involve all stakeholders from the start.

These results highlight the need for finding appropriate Instructional Design methods, depending on what type of learning tool is to be developed. Both these methodologies highlight a need to take the user groups learner needs into consideration, indicating these needing to be evaluated during development if not already known.
Evaluation of the polimarlish.id website [36], the website presented by Balderas et al. [25] or similar online tools could be used as inspiration or example implementations during a design process.

Regarding technical implementation of a Spaced repetition algorithm by Balderas et al. [25], a need to support user based profiles is highlighted for the algorithm to be able to track progress and adapt repetition based on needs. This includes teacher and student profiles where teachers can monitor student progress and create tests and training based on learner needs. Balderas also illustrate implementation of flexible data for some types of variables, for example nautical directions, positions, call signs, dates, degrees, numbers etc. This eases creation of new or varied exercises by changing these variables.

4

Discussion and Framework Creation

The results from the studies indicate considerations for a few important areas of focus for designing learning. This includes knowledge and skills relevant within the field of maritime communication and aspects surrounding how to design and create learning tools. Both considerations for methods to use in structuring the learning, and broader perspectives surrounding development are included.

The results do not touch on all important aspects of creating learning, neither do all approaches and claims have rigorous scientific evidence behind them. Learning and design theories have therefore been used to complement the findings, and guide the creation of a framework.

Instructional design, or instructional systems design, is a practice for systematically developing and delivering instructional materials. There are several theories available within this practice. The design decisions for this framework are to a large extent motivated by learning theories supported by evidence for Multimedia Learning by Clark and Mayer [40].
The results are also somewhat limited in what areas they cover. Much of the literature for instance deal with maritime English, simulator training and learning in a university setting. Many other areas of maritime communication are mentioned but not extensively. This can both indicate these areas as having specific importance but they could also happen to be the areas with most interest for research. This is somewhat exemplified by the difference in views towards teaching approach by Elhakim [27] where many maritime professionals, knowledgeable in other areas of the field, are more practically inclined and therefore also less keen toward to academic research. It could also be attributed to a search strategy which excludes several types of resources such as conference papers, books etc. A wider literature study could be beneficial to add to the results in this regard. In general more foundational scientific research on learning in the field would also be beneficial. Likewise could a more extensive interviews study with experts on a wider area of expertise focus learning towards other areas within maritime communication. In general the research methods used proved well suited and provided useful results.

A lack extensive empirical results regarding how to actually design learning tools for a maritime communication, alongside the evaluations of the preexisting material evaluated, highlights a gap in the field, a mismatch between content and Instructional Design.

Additionally, a lack in continuous learning for maritime professionals is another reoccurring theme from the results. With human failures being the main contributor to maritime accidents according to Maternová et al [2], an absence of continuous, well designed education to assure competency can contribute to negative safety at sea. This also seems to be a missing from aspect in the research literature.

4.1 Determining Learning Content

When initiating the creation of a learning tool or environment one needs to decide what knowledge and skills are to be included, what is the substance to be learned. There are alternatives for how to decide, a common method, complementary to Instructional Design, is Backwards Design [41], which emphasizes identifying what the end goals for learning are, determining when they are reached, and then designing learning activities to reach them.

The importance of developing Higher Order Thinking Skills (HOTS) and deep learning skills as mentioned by Kudryavtseva et al, Jamil et al and Guo et al. [32, 9, 29], can also be related to thinking skills presented by [40], divided into creative thinking and critical thinking. Creative thinking involves skills such as generating, creating and synthesizing novel ideas and critical thinking deals with evaluating, analyzing and deciding. Clearly defining the specific thinking skills and also relating them to the specific context they will be utilized in, for example a job-specific role, is important [40]. This is related to what Bjørn et al. [26] highlight as important in using Situated learning regarding simulators, in 3.3.0.3.

Misdirected learning where the knowledge gaps of the learners are not filled is common [40]. With this and the results in mind an importance of identifying a target group appears. The learners in a group have a set of previous knowledge, motivations to learn and common and individual properties which impact how to best create a good learning environment around the substance. Grouping could be done for the specific profiles identified, Exam-focused learners and Work-focused learners in the context of university students as well as the job-group of VTS-operators. Additional evaluation of what learner groups to focus on would seem fitting. Evaluating broad groups during the design process of a learning tool, or including options for evaluation of individuals and targeted groups, such as a class, within the tools themselves seems pertinent.

To successfully implement a backwards design, the selected learning substance should be mapped to the differing requirements of the identified target groups. One-size-fits-all content cannot satisfy the motivational and practical boundaries separating different student profiles.

- For Exam-focused Learners -typically lower-grade university students characterized by high external motivation- the content must prioritize foundational technical knowledge. This includes establishing a strict compliance baseline regarding standard VHF-radio terminology, syntax translation, and memorization of the IMO SMCP to safely satisfy examination and regulatory.

- For Work-focused Learners and VTS Operators, the instructional content need more transition from basic vocabulary drill-sets and focus more on complex scenarios, VTS-response strategies, distress transmissions, and the social dimensions such as cross-cultural communication.

Mapping the content most likely requires a structure where concrete, lower-level communication skills -such as radio channel management, standard phrasing, and verbal clarity- ties to and builds upon higher order skills. As highlighted in the subject interviews, these higher-order attributes include real-time risk assessment, situational awareness, and stress handling under high tempo conditions.

Content designed for specialized groups could consider previous industry experience and integrate new skills as an extension for students. For example, VTS-specific content modules could target niche competencies such as coastal navigation, and not as standalone subjects, modifications of general maritime communication principles.

As the both the interview and literature results point to, the use of relevant guiding documents can help inform what learning content is important to include. In general the IMO Standard Maritime Communication Phrases (SMCP) seem to be a central resource for language and for VTS-related learning the IALA-guidelines are presented as the go to source. To specify, IALA has a collection of documentation such as standards, manuals and guidelines for most aspects of maritime navigation. Among these, 26 pertain to different aspects of VTS and a few of the 26 deal with VTS-communication, for example G1132 VTS Voice Communications and Phraseology [42]. Depending on what the focus of learning is, evaluating and using relevant guidelines among these seem fitting.

As highlighted in the interviews, certification is an aspect to consider. Therefore, depending on what has been identified as goals, skills and what group they pertain to, identifying any necessary certification requirements is important. Will the learning group for example require GOC or ROC certification for their radio usage. This adds an additional guiding element to the content choices.

As the interviews indicate the consideration of previous knowledge should also include regard for earlier experience in maritime communication and the created learning should build upon these skills. For example any VTS-specific skills and knowledge identified as important should be related to and seen as an addition to any foundational maritime communication competencies and not a standalone skill set.

4.2 Choice of Learning Approach

There are many ways to design learning, both in general and in a digital setting. E-learning which doesn't have an unambiguous definition, is defined by Clark and Mayer as "instruction delivered on a digital device that is intended to support learning of knowledge and skills that apply to work-relevant performance" [40]. E-learning can be synchronous or asynchronous, where asynchronous refers to learner paced formats which can be accessed and interacted with independent of time, some examples are online tutorials, video lessons, games or simulations. Synchronous e-learning instead refers to time dependent learning such as instructor led virtual classrooms. Asynchronous e-learning will be the focus when discussing the creation of learning here and in the framework.

4.2.1 General Considerations

A major aspect in learner theory, also identified as important in the studies, is active processing, where the learner is psychologically engaged. Cognitive science can help to create an understanding for what active learning strategies -behavioral engagements-, as defined by Kudryavtseva [32], lead to a desired psychological and cognitive activity. Mayer and Moreno [1] present a Cognitive Theory for Multimedia Learning (CTML) which incorporates several general theories from cognitive science such as Cognitive Load Theory (CLT) [43] and Dual coding [44]. This multimedia learning theory can then be used to anchor Instructional design choices in cognitive science and learning theory. Active processing as defined by Mayer and Moreno involves the learners creating their own understanding of new material by mental organizing and integration of preexisting knowledge with the new, as illustrated in figure 4.1.

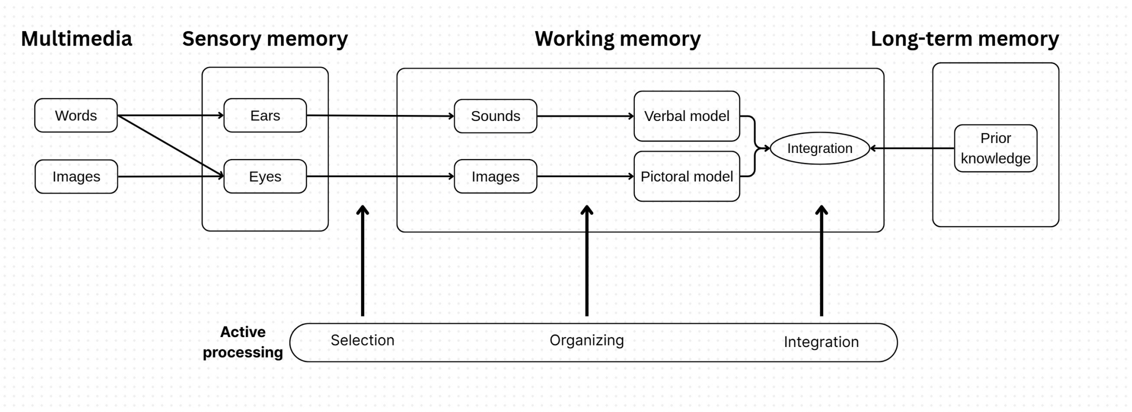

Figure 4.1: Cognitive Theory for Multimedia Learning (CMTL) with Active processing. Based on from Mayer and Moreno [1].

There is according to CTML a capacity for how much the channels of our working memory can handle, in the same sense as for cognitive load. This is historically stated by Millers law [45] to be 7 ± 2 bits of information while more modern sources indicate it likely closer to to 4 ± 1 [46]. There is additionally time limits surround how long information can be retained in working memory as shown by Peterson [47], where a majority is lost after around 20 seconds.

Three types of demands connected to this lack in capacity, which relate to active processing are *extraneous processing*, *essential processing* and *generative processing* [40]. Similarly to extraneous load in CLT, extraneous processing is often connected to how information is presented, and encompasses unwanted cognitive processing which doesn't support the learning objectives. Essential processing is instead processing dedicated towards representing the material, mainly associated with selection from sensory memory to to working memory. Generative processing, involving the deeper understand of the material, connected to organizing and integration, and is the most desired type of processing created by the learner trying to make sense of the material. One of the most common pitfalls when developing learning is overloading our working memory capacities, especially by producing to much of the wrong kinds of processing and too little of the desired kind.

CMTL presents several principles when creating e-learning that are proven to minimize extraneous processing, manage the essential processing and promote generative processing [40]. There are for instance six principles concerning different aspects of how to implement graphic and words together.

1. Multimedia principle - Learning is enhanced by combining words and images, connected to our capability to process these sources separately, see 4.1.
2. Contiguity principle - How words are spatially or temporally placed impact how easy the information is to process.
3. Signaling principle - Inform how *cues* can be used to guide attention.
4. Modality principle - Speech is processed separately from text, leading to a combination of speech and graphics being effective, especially for more complex information.
5. Redundancy principle - Informs when and how to combine text, graphics and speech as to not cause cognitive overload.
6. Coherence principle - How to avoid unnecessary words or images that subtract rather than add learning value.

Some active learning strategies, presented by Fiorella and Mayer [48] can help foster generative processing. This includes such as *Summarizing* material, *Imagining*, *Self testing*, *Self explaining* or *teaching others*. A common thread is having the learners create their own mental representations. A concrete example for this in a maritime communication setting would be asking a learner to explain how VTS communication is structured based on an instructional video, either to themselves, for instance via a writing exercise, or perhaps creating a presentation explaining it to a classmate.

Use of examples is another strong tool which can help reduce cognitive load for learners, especially when introducing a new subject. Clark and Mayer provide some evidence based principles for effective use.

1. To providing at least two examples, paired with practice exercises when the content is complex. When tasks are complex they can induce cognitive load in

new learners leading to a need to present worked examples before the learner can practice the content. Simpler content is learned more effectively with mainly practice.

2. Including self explanation questions or exercises helps ensure engagement in generative processing, especially important for learners who tend to skip worked examples since self explanation forces activity. Also by having these questions and exercises targeted towards rationales for why something is done a certain way it is possible force deeper analysis. An example pertaining to maritime communication could be asking the learner to explain why it is important to use a specific phrase or sentence structure after presenting a series of back and forth in a communication scenario.
3. Fade the examples to problems as competency grows by letting learners complete more of the steps in an example as they learn more.
4. Use the multimedia principle well for image, sound and text for examples in a good way as to not produce extraneous load which would minimize the benefits.
5. If wanting to teach strategic tasks involving more general problem solving methods, use varying contexts and place different examples next to one another for comparison. This is to produce so called transfer learning where the ability to adapt skills to new situations is the goal.

After relevant thinking skills, have been identified and related to a specific context, they should also preferably be implemented in a work authentic context [40]. Doing this with *simulators*, or *applied problem solving* in a context scenario with *dialogue plus mentoring* has proven especially effective, based on a meta analysis on critical thinking by Abrami et al.[40].

For teaching thinking skills, using a focused direct instruction which includes how an expert would act in a situation, followed by guided practice is effective [49]. A communication example would be a video showing a professional going through a communication scenario, while explaining why they respond the way that they do, what thinking patterns or problem solving steps they follow. Then using an exercise or assignment where the learner is asked to analyze effective and ineffective application examples. It would be important in such exercises to provide proper constructive feedback, either provided by the expert or by the system.

Simulators should as mentioned in section 3.3.0.3 facilitate exploration and experimentation. When making use of communication scenarios in a simulator setting they benefit from being as realistic as possible. Chernikova et al. [50], note in their meta-analysis on Simulator Based Learning (SBL) that simulators are especially effective for problem solving, but show weaker effectiveness when practicing communication and teamwork skills. They also point to cognitive realism as the most important aspect, that is the experienced realism. There are several options available for maritime simulation, such as more realistic but complex bridge simulators, VR-simulators and also more simple, low emersion screen based simulators, preferably with graphical interfaces exemplified by those presented by Sadowski [35]. Using simulators as a tool to increase realism in a structure with direct instruction and guided practice as mentioned above is an effective combination.

Dialogue plus mentoring would seem harder to make use of if an entirely asynchronous online based setting is used. Dialogue usually takes place within a classroom in an on site setting but could give benefits through system guidance created by knowledgeable peers. The instructional strategy of a flipped classroom discussed by both Kudryavtseva [32] and Jamil [9]. Creating a tool which includes preparatory material allowing for implementing discussions, peer feedback and other social dimensions which are less suited for an online environment might in some cases be preferential to an entirely digital structure. A flipped classroom, or rather what Clark and Mayer [40] term pre-training that decreases cognitive load during a simulation practice is a good option. An example of this for a simulation is an introduction session where all functionality is explained and can be tried out. This is especially true if there is desire to create more challenging scenarios or simulators for more advanced learners, such as for the Work-focused learner group. The Work-focused learner group might also benefit from a flipped classroom for practical practice of cross-cultural communication -deemed important from the results- more easily in a collaborative setting, as they can make use of the limited time in the classroom to interact with others instead of practicing basic components. The same is true for Maritime English, and the social approaches to learning of it mentioned by Jurkovic [3], with pair work, dialogues, role-play or projects based approaches highlighted as teaching methods.

For Exam-focused learners, linking basic SMCP phrase memorization or other terminology with real scenarios is recommended. Either using simulations or via case-based teaching, with simplified accident cases. The exercise designs by Ferreira [28] and Balderas [25] exemplify this, see 3.3.0.2.

A game-based learning approach, such as the Gamification of maritime English phrase practice presented by Sari et al. [36] in 3.3.0.2 is another optional approach, especially if there is a desire to increase motivation when practicing basic concepts. Effectiveness of games in learning present with mixed levels of evidence, although some characteristics have been identified as effective [40]. This includes

1. Creating short games **focused** on specific target skills.
2. Prompting the player to practice the targeted skills.
3. Embed feedback on how the player exercised the target skill.
4. Increase the challenge level and change contexts for practicing the skill
5. Games usually peak interest and produce a positive emotional response.

Instructional videos are a widely used and generally a useful learning tool if implemented well. They can either be incorporated within a design or as standalone content, as was the case with videos included in preexisting D-SMART educational material. Videos can take several formats, such as online lectures, demonstrations or tutorials where an instructor illustrate how to do something, or documentaries or other narrated footage. Clark and Mayer present some principles for instructional videos [40].

1. Apply the Multimedia principles.
2. Consider including a first person perspective for demonstrations.
3. Having an instructor drawing while lecturing instead of referencing already created material.
4. Use Generative activities within pauses in videos or in between videos.
5. Videos benefit from the instructor conveying positivity.

Taking advantage of social aspects are generally important to make the learner feel more connected to the presenter and material. This also involving for example looking into the camera, using polite phrasing and directing the learners attention with gestures.

Practice is another important aspect to include, where repetition of knowledge and skills helps to integrate them, while doing so in an active way. There are some relevant evidence based strategies presented by Clark and Mayer [40], namely.

1. Just the right amount of practice should be included based on how essential the subject matter is and if time is limited.
2. Spread out practice among different learning events, so called spaced practice or spaced repetition, promoting an increase of information stored in long term memory [51].
3. Use Scaffolding based on the identified level of learner knowledge is used to guide them where needed to reach potential. The framework from Quintana et al. present a comprehensive scaffolding strategy especially for e-learning [52].
4. Consider the Multimedia principle also when creating practice.
5. Give explanatory feedback on practice performance, for example using Hattie and Timperlys four feedback levels [53].

A spaced practice algorithm such as the one suggested by Balderas in 3.3.0.2 could be implemented to tailor the repetition. Repetition practice exercises or similar could then be presented more or less often based on learners previous results.

The short time frames for learning for especially VTS-operators mentioned in the interviews 3.2.4 indicate a need for trying to foster internal motivation habits facilitating more long term self motivated approach where learners keep up to date of their own accord. It also indicates a need to create educational material which learners can access after meetups. Feedback is generally an important aspect to consider in learning, both when self provided and if by others, it is also often connected to assessment. An option to create more long term individually owned learning could involve incorporating more self assessment practices for operators which provide self feedback, which require less external intervention and guidance. Self provided feedback is also an active learning strategy especially fitting for more experienced learners who can more accurately evaluate themselves [40].

Content can also be organized in different ways. For example the preexisting video material, presented in section 3.1 being categorized based on different knowledge and skills. Janssen et al. [30] suggest organizing content based on the VTS intervention ladder while Balderas et al. [25] partition content hierarchically based on SMCP categories. Splitting content based on basic skills and then separately more advanced aspects such as identified thinking skills can create options for progressing through the material.

An important aspect independent of what categories are used is splitting content up in chunks with the right amount of information as to not create extraneous load for the learner, this is called the Segmenting principle [40] or Chunking [45]. There is also a risk of to Essential overload if this is not considered where learners miss some essential aspects among all the information creating difficulties further on in the content. Additionally more specific structures already mentioned such as Direct Instruction or pre-training are strong options, where the preferred choice depend on the situation. For example using more pre-training for practicing more advanced content.

What control and navigation options are afforded within the structure is also important to consider, both for learning and usability. A strength of synchronous learning is the control afforded the learner where they can chose subjects, pace and chose their own approaches to an extent. Which degree of freedom is preferable to allow depends on several factors. This is the balancing of so called Learner control and System control. Three main aspects are controllable in this regard according to Clark and Mayer [40], Content selection, Pacing and Access to learner support. How much control to include depends a lot on the meta cognitive skills of the learner, that is how skilled they are at structuring their own learning in an efficient way. Generally learners are not skilled in this regard and what learners prefer does not often correlate with what is most effective for learning [40]. There are also aspects regarding motivation where system control is indicated to create more external motivation and learner control more internal motivation [54]. A strong approach is to use so called Adaptive control where system control is limited to early stages which creates a structured background and clear goals to build competence. Then as the learner progresses and gains confidence, they are gradually granted more learner control where they can choose activities, to maintain autonomy and situational interest [54, 55]. Additional options include making important learner events the default, giving all learners pacing control and to offer guidance in more open ended complex environments [40].

4.3 Wider design and development considerations

When designing a learning tool there are many broader aspects outside the specifics of how to create good learning. As mentioned by Harrington [7] the ADDIE model (Analyze, Design, Develop, Implement, Evaluate) for Instructional Design is one of the most widely used ways to structure a development project of learning. An alternative design model for e-learning, which incorporates a more iterative process, is the Successive Approximation Model (SAM). This model focuses on development of a less perfected design but incorporates several iterations of perfecting the product. It includes a Preparation Phase: with stakeholders to gather information and establish initial ideas. Iterative Design Phase: Involving creating initial prototypes, testing them, and gathering feedback, with a goal to fail fast and early so that the design can be refined before significant development occurs. Finally an Iterative Development Phase which focuses on the actual build of the e-learning course, moving from an "Alpha" to "Beta" and then final version, with evaluation at each step [56]. As an agile more iterative approach is commonly used in software development, the SAM model could be a strong alternative. Both Harrington [7] and Verstegen [8] also indicate a need to use more targeted design methods for certain types of learning tools, the Four-Component Instructional Design (4C/ID) model and SLIM methods respectively. These methods are also interesting options to try during development of simulators or simulator scenarios to evaluate their usefulness, even if they are not currently widely in use.

An important consideration during the Analysis stage using the ADDIE model, or including as an aspect to be iteratively evaluated if using SAM, is identifying what types of thinking skills are needed. A possible option for this is performing a Cognitive Task Analysis (CTA) for an identified target group. The interviews performed within this project can be viewed as an example CTA presenting some important thinking skills. Software components also need to be developed in connection to the identified thinking skills, what *data sources*, *examples*, *case scenarios*, *activities* or *thinking processes* need to be represented.

Considering additional user groups for the learning tool is another important part in the design process. The learning tool might not only be used by learners directly but by teachers or organizers. Consideration of what these users can do and adapt when dispensing learning is important.

This ties into the aspect of how dynamic a learning tool is. Designers can create more fixed, ready to use tools which are plug and play, or tools which include more flexible aspects. The design could for instance leave room to add additional practice exercises or a new simulation scenario. This also extends to designers having to decide how much power teachers should have to modify the learning experience versus what remains system controlled.

The flexible data structures usage mentioned by Balderas [25] is an example of such a dynamic consideration. There is a need to decide what data structures are preferable to leave as adaptable, either to allow for future additions to a dataset, for example adding new English phrases which could then be used to fill preset data variables. This can also allow for easier implementations of variance. This by creating certain types of data and templates for exercises which can be filled in specific ways by the datatypes one can facilitate easy creation of new exercises. The use of a spaced repetition algorithm mention in 3.3.0.4, used by Balderas is another technical consideration where this could allow for more individualized user adaption of a learning tool. A technical requirement presented which connect to several of these considerations is allowing for individual user profiles to base these adaptions of. Either a learner profile for a spaced repetition algorithm, a teacher or developer profile to adapt what exercises, tests, simulation scenarios or similar is presented requires the technical design to allow for it.

Technical limitations as well as resource constraints are a connected to these points. There is a difference between what in a conceptual design would be optimal for learning and what is possible to implement, either limited by expertise available, expected development resources or a time frame. A fully fledged VR-bridge simulator incorporating communication training as a facet could be a very strong learning tool but is a complex and demanding creation. When designing learning implementation in the wrong way can often have a detrimental effect, such as accidental creation of unintentional extraneous load for the learner. It then appears preferential to create tools that implement theories and methods, such as those discussed in section 4.2, in a well thought out and comprehensive way in lieu of complexity.

There are also aspects regarding how to actually implement certain concepts, for instance leaner control and navigational aspects. Principles from more software oriented fields like Interaction Design (IxD), User Experience(UX) or UI-design might be useful for inspiration.

Cooperation between individuals with complementary backgrounds during a development process appears preferential. As Verstegen et al. [8] point to, involving individuals with instructional design skills in the tool creation process is good. Incorporating input from subject experts in the relevant maritime communication field as well as people with technical expertise could also help combine different factors in an optimal way.

As presented, several of the articles in the result section, or software designed in conjunction with the studies, present concrete examples of implementation which could be used as inspiration during a design process. However keeping discussed design principles in mind as to not just copy an implementation without understanding the effectiveness of learning in its design appears wise.

4.3.1 Evaluation of existing material with design theory

Initial evaluations of the current educational material shows use of a slideshow video format driven by AI-based narration. While these voices present technical information at a slow, accessible pace, expert operator interviews reveal a major pedagogical drawback: a lack of interactivity that forces a user into a state of passive information consumption rather than active psychological engagement. To transition these materials from passive media into active learning tools, developers can implement structural modifications rooted in Mayer's segmenting principle [40]. By breaking continuous video narratives into short, user-paced blocks and interspersing generative learning activities -for example forcing the learner to fill in intentionally left out communication gaps or answer self-explanation questions from an operators chosen phrase structure- the software can stimulate more generative processing.

4.4 The framework creation

The discussions include considerations both for a "what" and "how" on different levels for creating and designing learning tools for maritime communication, as well as implications for what learning tools might be preferential to explore.
The relevant organizing characteristics for the intended framework are the following:

- Purpose - Guide the design and use of online learning tool creation and design in maritime communication.
- Intention - Provide important competences and useful approaches and consideration when designing the learning tools.
- Targeted learning or competencies addressed - Prior learning, relevant learning within the field of Maritime Communication, continued learning.

These alongside the three main sections discussed, **Learner content**, **Choice of learning approaches** and **Wider design considerations**. The separate sections were examined and some common theories and methods were identified and summarized, to then state some calculated generalizations and simplifications to decrease the distance between theory and application.

5

The framework

This is a conceptual framework for designing Maritime Communication Learning (MCL). The framework is designed to guide development, design and evaluation of mainly asynchronous digital learning environments within maritime communication. An overview of the frameworks three pillars is presented in figure 5.1.

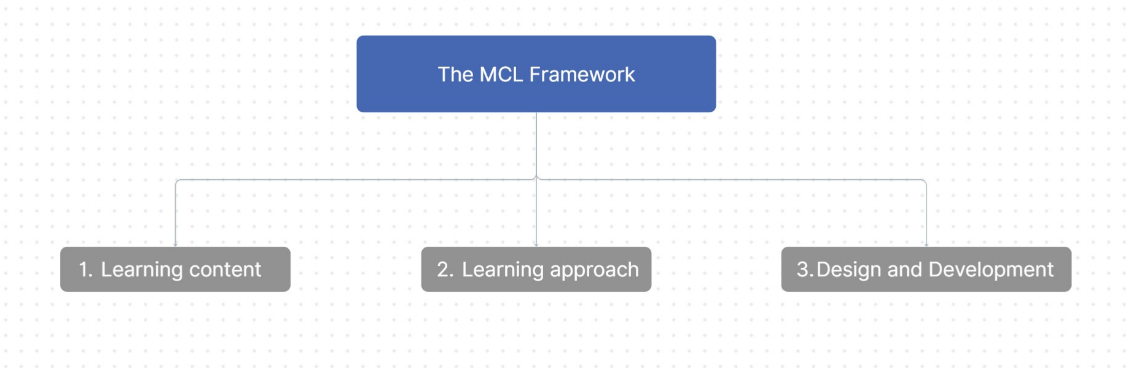

Figure 5.1: MCL Framework overview

5.1 Determining Learning Content

Before any design decisions are made, *what* the substance and the goals for learning are should be defined using methods such as backwards design.

- **Target group profiling and constraints:** Identify and categorize target groups early. Evaluate the group specific limitations, previous knowledge and time availability.
- **Knowledge and skill types:** Identify what types of content, for instance basic knowledge, Higher Order Thinking Skills (HOTS) or Deep learning skills are important to include.
- **Regulatory and professional anchoring:** Let the content be guided by international standards such as the IMO Standard Maritime Communication Phrases (SMCP) and the IALA guidelines. Anchor content to job-specific situations and also in relevant certification requirements, for example GOC or ROC certification for radio usage.

5.2 Choice of Learning Approach

This pillar describes considerations for *how* learning should be designed within the digital environment, anchored in Cognitive Science and The Theory for Multimedia Learning and other evidence based approaches.

- **Processing and Cognitive Load:** Consider structuring learning based on our limited cognitive capacity of 4 ± 1 bits and 20 seconds of information.
  - **Strive to minimize Extraneous Processing:** Apply principles for how to use words and graphics well, such as Coherence, Signaling, Contiguity and Redundancy. Incorporate evidence based principles for examples, especially for beginners and provide constructive and explanatory feedback och practice.
  - **Handle Essential Processing:** Consider how to divide your content into manageable chunks using the Segmenting principle. Base the division aspects connected to the identified learner group profiling, skill and knowledge types. Use pre-training principles or a flipped classrooms approach to practice key basic components before more demanding practices. Use the modality principle and present information via audio rather than text.
  - **Promote Generative Processing:** Make use of principles and practices which forces the learner to organize and integrate. For instance by asking the learner to elaborate on the material via summarizing, self, testing or explanations. Make use interactive methods such as simulation, games or collaborative practices with peers or experts. Include such elements also as regular and spread out practice as per the Spacing effect to increase long term memory retention.
- **Practical Method Choices for Maritime Communication**
  - **Faded Worked Examples:** Introduce complex scenarios, for example a complicated radio-dialogue including two solved examples and some self explanation questions, such as "Why did the operator use this phrase in this situation?". Then use an incremental transition over to exercises where the learner is required to apply their knowledge with less support. Such as creating their own standalone answers in similar communication scenarios, while still providing the learner with feedback.
  - **Simulator Based Learning:** Use simulators, from simple screen based interfaces to Virtual Reality, for practice of more complex problem solving for identified important skills. Focus on creating perceived realism as close to the emulated situations as possible and incorporating principles for handling processing and load correctly.
  - **Pre Training and Flipped Classroom:** Incorporate the asynchronous nature of a learning tool as pre-training, either before other real world learning or as a part in other e-learning. For example practicing SMCP-phrases or basic theory in pretraining could free cognitive capacity and time for role-play, group discussions or handling of more complex communication scenarios in a simulator. Especially

useful for learners with time limited education formats such as for working VTS-operators.
  - **Instructional Videos:** Design videos using evidence based principles. For example Coherence by removing unnecessary special effects, Signaling and Contiguity by highlighting screen elements in sync with narration. Segmenting can be combined with Generative activities of material where pauses are interspersed to leave time for processing but also filled with exercises or questions. Social aspect and personalization where the instructor is looking into the camera, using polite and conversational narration, or other ways of creating a feeling of social presence, should also be incorporated.

5.3 Wider Design and Development Considerations

A framework can not be applied in a vacuum but has to take system architecture, development processes and resources into account.

- **Development Method:** Choose an appropriate development model for e-learning content depending on the project. A classic waterfall approach such as ADDIE (Analysis, Design, Development, Implement, Evaluate) where each step is carried out in careful succession can be used. If more modern and agile methods are needed, it can be combined or replaced with the SAM (Successive Approximation Model) where simple prototypes are tested and iterated over as to not build a complex system which then proves wrong. Certain complex tools might also benefit from use of more targeted development methods for example developing simulators or simulator scenarios.
- **Evaluating Skills:** Include evaluation of user groups, tasks or skills if not already identified. Make use of methods such as Cognitive Task Analysis (CTA) to map hidden thought patterns or decision strategies for different areas of maritime communication.
- **Multi-user and System Control Flexibility:** Design the learning tool with consideration for both the intended learner and instructor. Balance what is system controlled and what a teacher can control and modify such as exercises, adding or changing scenarios or adjust datasets. Determine how much system control versus learner control over content, study choices and pacing should be given. Consider using an Adaptive control method where System control transitions into more Learner control as learners progress.
- **Technical Adaptability and Individualization:** Consider what to implement as flexible data structures to allow easily scalable content. Incorporate individual user profiles if individual adaptations are required, for example an individualized spaced repetition algorithm.
- **Resources and Pedagogical Rigor:** Maximize implementation of pedagogical principles and theories rather than increasing the technical complexity. It is for instance better to apply the learning principles perfectly in a screen based technically simple simulator than a misaligned in a

VR-environment causing extraneous load.
- **Cooperation Between Disciplines:** Make use of close collaboration between Educators or Instructional Designers, maritime professionals and technical experts during the design process.

5.4 Framework Utility and Scope

This framework is intended to combine insight from research literature, learning theory, design theory and knowledge within the field of maritime communication. The hope is that it can prove useful in several dimensions.
First, the framework provides guidance for members of development projects where learning tools and environments are created, either from the ground up or through continued development from the basis of already existing software.
Second, teachers and others who need to distribute learning could find use in the framework when developing learning within an already existing learning software.
Third, it can prove useful when evaluating already existing learning tools and environments and to guide improvements or additions.

The studies which form the basis for the framework alongside the framework itself contribute to the scientific tradition especially within the area of education within maritime communication where this is sorely needed. The framework might inspire further research and development within this context, such as showing possible directions of development within the D-SMART project, but also in a wider sense.

The framework would need to undergo evaluation to properly determine its actual usefulness and point to possible improvements. Evaluation would preferably be done for each of the mentioned use cases, evaluation of development teams, teachers and designers perceived usefulness as well as evaluating effectiveness of learning created using the framework. The thorough approach would be using the framework in development to then evaluate it perceived usefulness by the developers. Alternatively evaluation could be performed by showing users the framework and evaluating expected usefulness. Evaluating the effectiveness of learning developed would be harder this way.

As a framework is a simplification of complexity in favor of usefulness, which brings risks such as over reliance, over simplification or over structuring [57], it is important to highlight the intended usage as a guide for where to focus efforts when creating learning. This might entail researching and evaluating if the recommendations are applicable in a specific scenario being explored. As the framework is focused on maritime communication specifically in a digital setting, while many of the principles and recommendations most likely could be applied in other domains, doing so requires extra caution.

6
Conclusions

The primary objective of this thesis was to answer the guiding research question: "What might a framework look like for development of digital learning tools for maritime communication?". This addressed by interviewing subject experts, performing a qualitative literature review to extract relevant scientific data, and integrating evidence-based multimedia learning and instructional design theories. The practical results of this methodology is the conceptual Maritime Communication Learning (MCL) framework. Organized into three fundamental pillars -Determining Learning Content, Choice of Learning Approach, and Wider Design and Development Considerations- the framework provides an actionable structure to guide the design, implementation, and evaluation of asynchronous digital learning environments.

The findings indicate that while technical knowledge and vocabulary standards (such as the IMO SMCP and IALA guides) are well documented, there is a risk that digital solutions can create unnecessary cognitive load and fail to cultivate active psychological processing required to develop Higher Order Thinking Skills (HOTS). The data analysis exposed a vulnerability regarding graduation skill retention. For VTS operators, the prolonged 4-5 year intervals between refresher courses lead to skill loss, due to a lack of continuous workplace follow-up. The MCL framework could be used to help counteract these effects via the multimedia principles, assisting in creation of asynchronous digital learning tools that can be used at any time, which stimulate long-term memory retention rather than cognitive overload.

Practical implications of the MCL framework extend across dimensions of both software development and maritime pedagogy within the D-SMART project and beyond. For interdisciplinary engineering teams, such as the D-SMART development group, the framework can serve as a design guide that shifts the focus of software optimization away from purely technical complexity or aesthetics toward more pedagogical rigor. Implementing technically simple, screen-based simulations that adhere to cognitive architecture is proven to be significantly more effective than deploying misaligned, high-complexity tools that induce extraneous cognitive load. For maritime institutions and government stakeholders like Sjöfartsverket and Kystverket, utilizing the framework can facilitate creation of dynamic, individualized learning ecosystems. By using adaptive system controls, flexible data structures, such as individualized spaced repetition algorithms, operators can continuously interact with realistic, work-related communication scenarios outside of classroom environments. Given that nearly 70% of maritime accidents are traced back to human errors originating in degraded cognitive and psycho-behavioral processes, deployment of instructional tools constructed via the MCL framework provides an avenue to systematically mitigate communication failures and measurably enhance safety of life at sea.

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A

Appendix 1

SCOPUS

1. TITLE-ABS-KEY ((conceptual framework) AND (Maritime communication)) — 30 Results
2. TITLE-ABS-KEY (maritime communication) AND (digital learning) — 78 Results
3. TITLE-ABS-KEY((simulators) AND (communication) AND (Learning OR Training OR Teaching) AND (Aviation OR Maritime OR Marine)) AND (LIMIT-TO (LANGUAGE,"English")) AND PUBYEAR > 2006 AND PUBYEAR < 2026 — 161 Results
4. TITLE-ABS-KEY ((english) AND communication AND ((Lifelong learning) OR (ACTIVE learning)) AND ((online learning) OR (electronic learning) OR (Digital learning) OR (E-learning))) AND PUBYEAR > 2009 AND PUBYEAR < 2027 AND (LIMIT-TO (LANGUAGE, "English")) AND (EXCLUDE (SUBJAREA, "MEDI")) AND (EXCLUDE (EXACTKEYWORD, "Covid-19") OR EXCLUDE (EXACTKEYWORD, "Deep Learning") OR EXCLUDE (EXACTKEYWORD, "Machine Learning") OR EXCLUDE (EXACTKEYWORD, "Machine-learning") OR EXCLUDE (EXACTKEYWORD, "Artificial Intelligence") OR EXCLUDE (EXACTKEYWORD, "Convolutional Neural Networks")) AND (EXCLUDE (DOCTYPE, "ch") OR EXCLUDE (DOCTYPE, "bk")) — Sorted by relevance: Took first 100 Results
5. TITLE-ABS-KEY (("learning" OR "teaching" OR "education" OR "instruction") AND ("maritime communication" OR "marine communication" OR "vessel traffic services" OR "VTS" OR "traffic management")) AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (EXCLUDE (EXACTKEYWORD, "Deep Learning") OR EXCLUDE (EXACTKEYWORD, "Air Traffic Control") OR EXCLUDE (EXACTKEYWORD, "Machine-learning") OR EXCLUDE (EXACTKEYWORD, "Intelligent Systems") OR EXCLUDE (EXACTKEYWORD, "Algorithm") OR EXCLUDE (EXACTKEYWORD, "Prediction") OR EXCLUDE (EXACTKEYWORD, "Roads And Streets") OR EXCLUDE (EXACTKEYWORD, "Highway Administration") OR EXCLUDE (EXACTKEYWORD, "Artificial Neural Network") OR EXCLUDE (EXACTKEYWORD, "Machine Learning") OR EXCLUDE (EXACTKEYWORD, "Street Traffic Control") OR EXCLUDE (EXACTKEYWORD, "Urban Transport") OR EXCLUDE (EXACTKEYWORD, "Medical Education") OR EXCLUDE (EXACTKEYWORD, "Traffic Management")) AND PUBYEAR >

`2006 AND PUBYEAR < 2026` — 313 results

ERIC

1. `Maritime communication` — 32 Results
2. `(simulators OR gamification) AND (communication) AND (Learning OR Training) AND (online-learning OR Digital-learning)` — 95 resultat
3. `(english) AND communication AND ((Lifelong learning) OR (ACTIVE learning)) AND (( online learning) OR (electronic learning) OR (Digital learning) OR (E-learning))` — also sorted by, active learning and just research reports. 53 results
4. `(maritime OR marine) AND (Learning theory) AND (students)` — 25 results

B

Appendix 2

Intervjuguide

- Längd: 60 minuters intervjuer

Uppvärmningsfrågor

- Gå igenom kort bakgrund och syfte.
- Har du några frågor?
- Kan du berätta om din bakgrund i maritim kommunikation?

Teman

Maritim kommunikation: Kunskap och färdigheter

- **GT-fråga:** Vilka kunskaper och färdigheter utgör maritim kommunikation för dig?
- *Följdfrågor:*
  - Vilka är viktigast?
  - Vad är svårt? Något särskilt eller är det blandat?
  - Vad är lätt?
  - Är det några övergripande koncept som du tycker är viktiga?

Metodik som används av lärare/operatör

- **GT-fråga:** Vad finns för tankar runt upplägget av utlärande av kunskaperna, vad är viktigt där?
- *Följdfrågor:*
  - Vad används för metodik i arbetet?
  - Hur utbildar VTS?
  - Vad utgår de ifrån mest för dokument?
  - Hur bibehålls kunskaper?
  - Hur skapas kurser (om de finns)?
  - Hur arbetar ni mot att skapa den livslånga kunskapen?
  - Något du saknar eller tror hade varit nyttigt i upplärande av t.ex. operatörer?

  - Bygger koncept på varandra (progression, spacing, active recall)?

Målgrupp

- **GT-fråga:** Hur påverkar målgruppen ni lär ut till hur ni lär ut innehållet?
- *Följdfrågor:*
  - Hur påverkar olika bakgrunder inom gruppen?
  - Vad har störst inverkan från förkunskaper?
  - Skillnader i VTS-kommunikation (operatörer vs. de på båt)?
  - Hur går det med VTS internationella lagars implementation i Sverige (både nationellt och internationellt)?
  - Motivation till lärande: Interna eller externa motivatorer?

Teknik och digitala hjälpmedel

- **GT-fråga:** Vad tycker du är viktigt för teknik och digitala hjälpmedel som används i maritimkommunikationssammanhang?
- *Följdfrågor:*
  - Beror det på sammanhanget?
  - Teknik för lärande?
  - Vad tycker du om existerande Digimar-material?
  - Vad saknas i teknisk väg just nu?

Avslut

- Har du något du undrar eller några tillägg?
- *Notering:* Avsätt 10 minuter efter intervjun för egna anteckningar om sådant som inte framgår av en transkribering.

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