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Conceptual Modelling of the Use of Artificial Intelligence in Maritime Education and Training: An Exploratory Approach

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Abstract: The maritime industry has been experiencing a digital revolution and the high pace of digitalization is expected to continue with enabling new generation artificial intelligence (AI) utilization. There is no doubt that the impact of AI on maritime transportation in the future will be substantial. Therefore, it is important to have seafarers having the technological thinking and savoir-faire in the merchant fleet. In this study, an exploratory approach has been taken to establish a conceptual framework on AI utilization and implementation in maritime education and training (MET). A set of questions on AI application in simulator training, theoretical classes as well as mandatory safety of life at sea and ship security training were asked to experts and decision makers in the MET comprised of ship captains and academics. Furthermore, the same set of questions were asked to the recently popularized chatbot of the AI company OpenAI's ChatGPT to make a comparison of the answers. Acquired answers from both parties have been analyzed with respect to the maritime education and training literature to set up a framework regarding the utilization of AI in MET. Concludingly, the benefits, challenges, and limitations of using AI in MET were presented through an exploratory approach.

Keywords: artificial intelligence, maritime education and training, e-learning, continuous learning, simulation training.

1. Introduction

The maritime industry handles around 80% of global trade (UNCTAD 2022). This immense transportation capacity, this system is non-comparable to majority of other modes of transportation regarding the impact on global economics. Therefore, safe, and efficient maritime transportation is one of the focus areas of international organizations, governments, and other regulatory bodies as well as stakeholders all around the world. For such a system, digitalization is inescapable with concepts such as industry 4.0, blockchain, smart contracts and autonomous ships being the leading trends in the maritime domain (Dede et al. 2021; Köseoğlu et al. 2021). IT systems are expected to impact the maritime domain in the following years considering the increase in the number of vessels and complexity of operational processes (Alop 2019).

In addition to logistics outsourcing services, AI is considered to be playing a crucial role in the maritime sector in the upcoming years in line with the aforementioned trends. (Işiklar et al. 2007; Sharma et al. 2022). The next generations of seafarers are expected to be able to comprehend and communicate with AI powered decision support systems (Alop 2019). This comes with the requirement of establishing the mentality of future seafarers with ethical concepts as well as legal thinking by bringing innovative solutions and while creating an education and training environment that enables balancing soft and hard skills such as engineering and humanities (Allam 2016; Simmons and McLean 2020). As stated by Jo et al. (2020), the industry shows the tendency to enable new competencies for keeping up with the changes and remain relevant. Although maritime industry is expected to be at low risk to be automated completely, the implementation of technology is imminent. As Lee et al. (2019) presented, many aspects of the maritime industry including law, management, education, and operations is under the influence of automation to some degree, while International Maritime Organization encouraging the automation as well as trying to provide a framework for technical, safety and operational aspects of automation under the concept of industry 4.0.

MET required to be handled with a differentiating approach to be able to keep on track with these changes (Burke and Clott 2016). For preparation of seafarers for the digital transformation and digitalized seaborne trade environment of the near future, the Standards of Training, Certification, and Watchkeeping (STCW) regulations and competency list within it needs to be updated as well as stakeholders in maritime industry are required to reconsider conventional means of MET for enabling development and upbringing skills and supervised learning for the digital competency and technological tendency by AI implemented MET (Baldauf et al. 2016; Munim et al. 2020; Sharma and Kim 2021; Laperrière-Robillard et al. 2022). It can be argued that the main challenge remains between incorporating digitization opportunities and still being able to build necessary skills for a marine engineer and maritime transportation engineer (or deck and engine officers in general) which are strictly outlined by STCW model courses.

AI has been steadily increasing in utilization and implementation in various fields with beneficial functionality recently while being able to provide improvements in the field of education and training and setting new learning outcomes surpassing conventional methods (Pedro et al. 2019; Sharma et al. 2022). Currently the utilization of AI implemented systems made available with the developments in computer technology is influencing and changing conventional education delivery (Chen et al. 2020). There are various research of AI induced education proposals in the recent literature of MET including theoretical classes (Säljö 2010; Strijbos 2011; Mallam et al. 2019; Sharma et al. 2019; Bartusevičienė 2020; Simmons and McLean 2020; Scanlan and Hopcraft 2022) and practical training (Hontvedt and Arnseth 2013; Castells et al. 2016; Sellberg 2018; Hjelmervik et al. 2018a, b; Sellberg and Lundin 2018) as well as inclusion of virtual or augmented reality (Buttussi and Chittaro 2018). One of the better examples of AI utilization have been in the form of AI chatbot for Collision Avoidance Regulation (COLREG) by Sharma et al. (2022), where the authors have developed and utilized a custom chatbot named FLOKI and tested its applicability as a teaching aid for COLREG in addition to the study of Choi et al. (2018) on the development of chatbot framework for ship safety education. Even though it is still a long way for AI implementation, the concept exists and needs to be explored for creating a satisfactory and sufficient curriculum. Additionally, the importance of having competent deck and engine officers with technological tendencies and savoir-faire can be discussed to be substantial in the near future with the increasing applications of digitalization such as maritime autonomous surface ships.

In this study, an exploratory approach has been taken for evaluating the implementation of artificial intelligence as a tool in MET through the conceptualization of the use of AI in MET, while researching the benefits, challenges, and limitations of the involvement of such technology into conventional ways of education with qualitative data analysis.

2. Conceptual Framework

The role of artificial intelligence in maritime education and training is analyzed in a broad way within an explorative approach through the development of a conceptual framework. This framework for this study explores and brings the key concepts for the use of AI in MET by providing a structure and a guide for the researchers to have a clear understanding of these concepts. As also provided within the methodological background, the conceptual contexts are generated to bring more depth to the analysis of the use of AI in MET and major components within the conceptual framework are illustrated in Figure 1 and 2 by also considering the analysis of the results stemming from the interviews.

3. Methodology

To establish a framework on AI integrated MET, a set of questions was prepared regarding adoption (questions 1-3), implementation (questions 4-8) and evaluation (questions 8-10) dimensions and were asked to experts and decision makers in the MET comprise of ship captains, MET experts and academics. Furthermore, the same set of questions were asked to the recently popularized chatbot of the AI company OpenAI's ChatGPT to make a comparison of the answers. Four separate replications have been carried out for ChatGPT, where two of them with 3.5 Legacy version and two with GPT4 March 2023 version. Acquired answers from both parties have been analyzed with respect to the literature to set up a framework regarding the utilization of AI in MET. For the analysis process within the methodology, keywords and phrases matching with each other received from the human experts and AI were conceptualized for showcasing common concepts while different opinions of both parties have also been noted for further discussion. The demographics for the voluntary participants are given in Table 1 below.

Table 1. Voluntary Participants' Demographics.

Latest Rank	Experience in Maritime Industry	Education	Current Profession
Master	15+	Master	Maritime Lecturer
Chief Engineer	15+	PhD	Academic
Marine Engineer	5-10	PhD	Academic
OOW	5-10	Master	Academic
OOW	5-10	PhD	Academic
OOW	5-10	PhD	MET Specialist
OOW	5-10	Master	Maritime IT Engineer

The following questions have been asked to experts and decision-makers in MET field for exploring additional aspects of AI integration in MET, promoting a deeper understanding of the potential opportunities, challenges, and limitations.

1. What collaboration opportunities exist between AI researchers, maritime experts, and educational institutions to advance the integration of AI in maritime education training?
2. What are the potential long-term implications of adopting AI technologies in maritime education and training, both for the industry and individual seafarers?
3. What ethical and legal considerations should be taken into account when implementing AI technologies in maritime education and training, and how can stakeholders work together to address these challenges.
4. How can AI be used to facilitate remote and distance learning opportunities for supporting continuous professional development and lifelong learning (i.e., online courses, virtual reality simulations) for seafarers ensuring they remain up to date with the latest industry standards and best practices and what challenges must be addressed to ensure successful implementation?
5. What are the key factors to consider when designing and implementing AI-driven simulation training in order to ensure maximum effectiveness and accessibility for trainees?
6. How can AI-driven adaptive learning systems be used to tailor maritime education and training (including theoretical classes, practical classes, and simulator training) for individual trainees' needs, and what impact might this have on knowledge retention and skill development?
7. What are the potential applications of AI-driven scenario generation in survival at sea, cargo handling and navigational training, and how might this lead to more engaging and realistic training experiences?
8. How can AI be employed to analyze historical accident and incident data in order to develop more effective survival at sea, cargo handling and navigational training scenarios.
9. How can AI be used to help identify and address common challenges in practice (i.e., during emergency situations, cargo handling, watchkeeping) such as improving communication, coordination, situational awareness, and decision-making?
10. How can AI-powered data analysis be used to identify trends in trainee performance (i.e., areas of weakness, skill gaps) and develop targeted interventions to enhance the effectiveness of practical training (simulation training) outcomes?

4.Results and Discussion

Development of a conceptual framework for the integration of AI in the maritime education and training within an exploratory approach has led the results to bring solutions and make interpretations under different conditions to increase understanding, expanding knowledge, clarifying significant issues, exploring, and examining existing situations, and providing further research suggestions. AI integration to MET has been evaluated under three dimensions, adoption, implementation, and evaluation, which are given in Figure 1. Adoption refers to the collaborations between AI experts and specialists, industry stakeholders and academy, regulatory, ethical, and legal aspects, and potential effects on seafarers. Implementation dimensions comprise of continuous learning, practical training (simulation training) and theoretical classes. Finally, evaluation dimension represents the AI utilization for evaluating trainee performance and AI application performance.

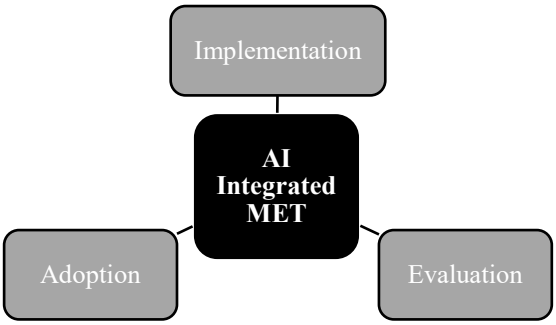

Figure 1: Dimensions of AI integrated MET.

4.1 Adoption

Common statements from both experts and chatbot included the collaboration between MET specialist and AI specialists for developing and optimizing the learning algorithm for AI for each task:

"…The maritime industry's unfamiliarity with AI applications can be resolved with the collaboration of AI researchers and MET specialists for enabling a complete digitalization of MET."

While this approach would also enable setting the minimum standards in the quality of the trainers, utilizing an unsupervised AI training module in the recent future will not be enough for a complete MET environment. Fast information access and transfer may allow an intensive education model with trainees acting as assistant teachers rather than students since AI offers brief and practical information which can be verified.

Regarding practical training, generating simulated environments is costly and procedural generation of onboard virtual reality environments with the AI is possible event with current technology. Development and integration of AI-powered simulators will help seafarers to maintain their employability. AI integration will surely enable a sustainable scientific infrastructure for academy and industry collaboration as well with reduced cost and time, opening new opportunities for experiments and measurements as stated:

"…Procedurally generated simulation trainings should provide the necessary randomness for evaluating the decision-making capabilities of seafarers as well as reduces the amount of work MET experts need to put in for scenario generation. They may just train the AI and provide a random seed with minor interventions."

Ethics and regulations are another important criterion for AI adoption, while AI can also enable objective approaches:

"…AI is unaware of ethics and should provide an objective approach while human factor poses a danger for ethical breaches currently…"

On the other hand, establishing data privacy and protection is a must with accountability. Establishing independent audit and service approval processes with clear definition of legal limits and liabilities and compliance with these laws and regulations must also be considered before generalization of AI integrated MET.

4.2 Implementation

The introduction of supervised AI training tools may provide cost effective MET with increased efficiency by personalized continuous learning and distance learning. AI-prepared training aids also contribute to this argument. This combined with learning tracking with MET experts increases the efficiency of MET even more. The experts meet in the common ground of supervision and combined AI learning with conventional methods of MET, without any qualified person to supervise AI induced learning whether it is distance or in-class, one participant states:

"…. Who will decide if the AI says it wrong?"

For simulation training, AI-driven scenario generation has been emphasized by the majority of the participants and chatbots as well. Combined with adapting learning, simulation training can be adjusted according to the requirement of the trainee. AI-enhanced simulation training is a more generalized concept, that supervising MET experts and AI experts working together to optimize the training experience, including difficulty levels, deficiencies realism as well as scalability, interoperability, and user-friendliness. This can be further enhanced by collaborating with shipping companies, which can feed event data such as near miss,

accidents, type specific applications and rare events, which may provide a valuable experience for each seafarer prior their working onboard.

4.3 Evaluation

AI-enhanced evaluation for MET establishes an environment for achieving the goals of education by determining the measurement and evaluation criteria more accurately and more precisely. Optimum performance evaluation can be achieved by eliminating human element, hence biased evaluation, and it reduces prediction error for weaknesses and strengths of the trainee, uncovering performance trends and skill deficiencies. Enabling tailored training paths, targeted interventions and setting new training outcomes based on performance are the strong suites of AI integration to MET according to participants.

Utilizing AI for evaluating the performance of the trainees also provides feedback on the performance of the training elements, which can further enhance the effectiveness of lecturers that can be correlated back to the re-planning of training parameters in a perfect loop of planning-monitoring-execution-analysis.

4.4 Limitations

Certain limitations have been stated by participants considering three proposed dimensions of AI integrated MET. Regarding data availability:

"… AI should be trained continuously with a healthy data stream while the data will be gathered from the stakeholders in maritime industry, who shy away from sharing their data. This would affect the sustainability of AI applications in MET. The stakeholders must be convinced that AI will reduce the cost of MET and beneficial in the long-term, then maybe IMO or other regulatory bodies can find a way for data sharing."

Another limitation emphasized is the vocational necessities of MET, which is discussed as follows:

"…Working on a ship is unlike any other job, it requires discipline, self-confidence, and most importantly, knowledge and attention.…Maritime training is not just vocational training; it is personality training."

"…It is necessary to educate students from different cultures in the same way of thinking. If one of them interprets, for example, COLREG rule 13 differently, it will cause accidents. Even in the classroom, we have a hard time training as it is."

The participants also discuss that these concerns for AI applications in MET are also present for conventional MET. It should be noted that a one-size-fits-all solution is not available for MET, but AI

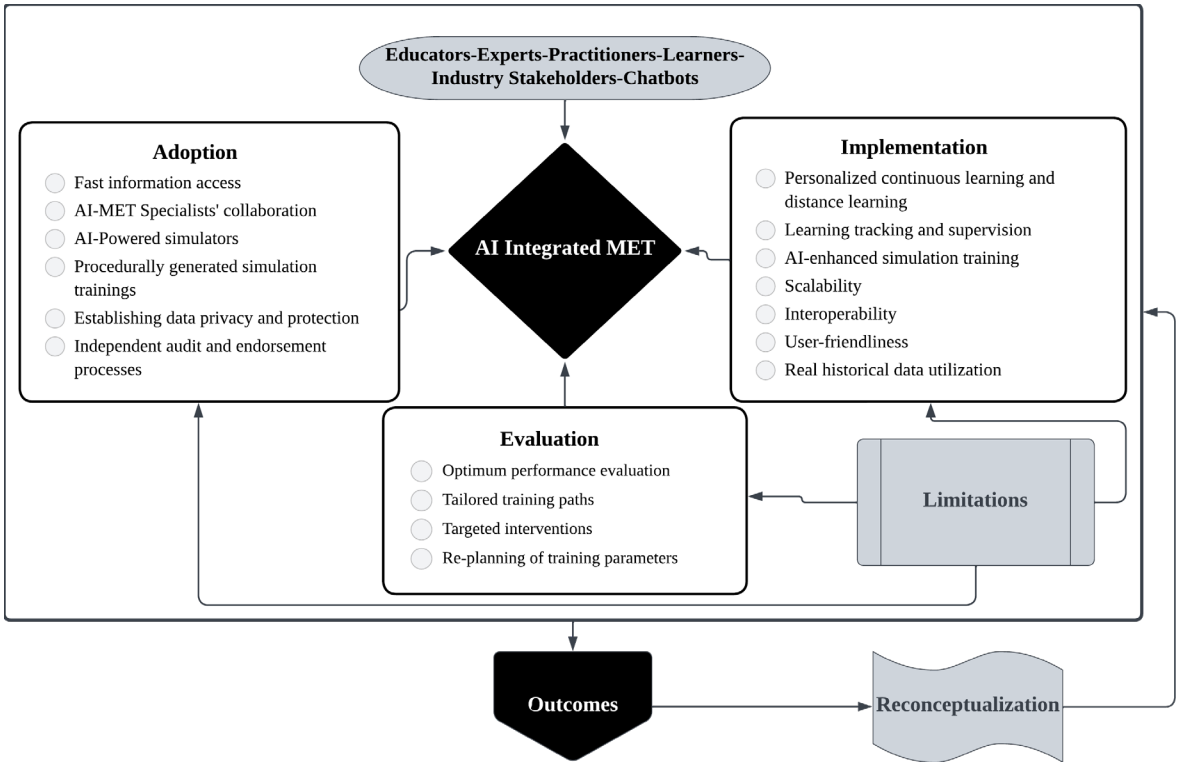

Figure 2: Conceptual framework of AI integrated MET.

integration is to be surely able to open new ways of preparing seafarers for the future of maritime transportation as the framework given in Figure 2 sets out the criteria and concepts deemed necessary.

5. Conclusion

Concludingly, the benefits, challenges, and limitations of using AI in MET were analyzed and examined by using data received from human experts and ChatGPT through an exploratory approach. When compared, MET experts and both legacy version of ChatGPT and recent GPT4 version answered the questions similarly, with expected answer quality between ChatGPT versions. The results indicate that in the current conjuncture of MET, AI may provide benefits and support to a certain extent on providing perspective to students in the form of research, basic knowledge, project development and career pathing. For MET lecturers, AI tools enable to develop multiple scenarios for simulator training, analyze big data packs and ensure interactive class environments and the tools can also be used as a personal teaching assistant. One of the major current challenges for the lecturers is considered that the information acquired from the AI tools may not be reliable and valid, hence it may cause a cumbersome workload for the lecturer to check the information received from the AI platform as opposed to researching the information from the already acknowledged sources and academic material. Overall, although it is clear that there will be benefits of using artificial intelligence platforms in maritime education and training, as in many other fields, it still is considered to be a situation that requires improvement and progress.

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