AUGMENTED REALITY TECHNOLOGY AS A TRAINING TOOL

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Abstract. The current study explores the advanced technology of Augmented Reality (AR) as a digital tool of Industry 4.0. As such, we investigate the potential use of AR for the training of seafarers, as a new technological tool aiming to increase their safety and operational effectiveness. Based on existing research of training through technology, we have performed a gap analysis between current training methods whereas, we are discussing the adoption maturity level and the technological obstacles. Our research is qualitative in nature, by means of in-depth interviews. The study consisted of interviews with twenty-four people from the shipping industry aiming to provide fresh insights about the augmented reality in the industry. Augmented Reality in shipping is currently at a very early stage; apparently, around half of the interviewees are not welcoming the technology in general and especially the use of AR in on-board training. According to our findings, the market seeks for the adoption of AR in on-board operations rather than training. Practical implications are also outlined.
Keywords: *augmented reality technology, onboard training, shipboard operations, industry 4.0, maritime, shipping*

Introduction

In shipboard operations, there are three major factors which need to be considered concerning the on-board personnel: safety of the crew, safety of the ship and cargo and environmental protection. However, under all circumstances, safety comes first. Shipping companies support the human safety at sea, and thus, rank it as their very top priority. It is a known fact that to achieve a high level of safety, on-board personnel need to undertake extensive training, possess the right safety equipment and operate in a safe working environment. However, working on-board is considered a dangerous workplace. The nature of the seafaring job, the characteristics of vessels and cargoes, the psychology of the seafarers while being at sea for months, is what causes lack of attention on safety procedures. Human failures are also common as they work under pressure and it is unlikely to underestimate potential risks (Genc, 2019). Another existing gap has been the lack of communication among crew members. A multicultural crew means that people from several countries and/or cultures interact regularly as proposed by Adler and Gundersen (2008) as well as Gausdal and Makarova (2017). An extensive literature review of the impact on crews on maritime safety, (Berg and Lune, 2016; Gausdal and Makarova, 2017) concluded that intercultural cooperation, communication, fatigue and language skills of a seafarer are the most important issues that contribute to maritime safety on an individual level.

The continuous crew changes and the fast operation cycle do not allow time effective safety training prior to boarding (Markopoulos and Luimula, 2020). Judging by the current efficiency of training on-board, development of new technologies will result in a more effective, rather than a costlier method of training (Mazzarino and Maggi, 2000).

The International Transport Workers Federation (2017) supports the idea that the key to maintain a safe shipping environment and keeping our oceans clean, lies on all seafarers across the world observing the highest standards of competence and professionalism in the duties they perform onboard. The International Convention on Standards of Training Certification and Watch-keeping for Seafarers (International Maritime Organization, 2020) (established in 1978, amended in 2010), sets these standards, governs the award of certificates and controls watch keeping arrangements. A seafarer needs to learn the working environment thoroughly, and competently analyse any risks. This knowledge and these skills need to be gained through proper training and appropriate practice in the use of equipment, tools, systems, safety procedures and emergency plans.

The high level of collaboration among individuals across departments and the trust between crew and on shore managers is a matter of safety. Lack of collaboration may lead to dire consequences. The uncertainty between crew and on shore managers will impede knowledge sharing at all levels. Moreover, horizontal communication is essential for individuals to build trust and understanding, therefore a requisite for collaboration and knowledge sharing (Fei, 2011). This research investigates a new approach in on-board training to explore the potential of advanced technology usage and to improve safety. A theoretical hypothesis is formulated in a way that a rapid and substantial technological progress of industry 4.0 occurs today. The main objective of this research is to identify the challenges of implementing AR technology as an educational tool for on-board training. “AR, can be applied in the training of qualified seafarers by combining real world data (technical indicators of different aggregates from the ship’s power system, location and development fire, flood water, etc.) with computer generated data from the simulation complexes” (Bakalov et al., 2018). AR systems can communicate with various sensors in real-time, which can offer a broad range of training affordances as Limbu et al. (2018) explain. This technology allows learners to examine all information in a stimulating and exciting setting that combines a traditional learning content with the world’s most innovative virtual objects (Ismaeel and Al Mulhim, 2019). It is intriguing to investigate whether there is a possibility of improving safety procedures in shipboard training by using AR. Today, AR is used in the navigation of ships, mainly by companies from Scandinavia, and as a pilot or prototype model in marine engineering. No one has ever used it for training seafarers on-board ship.

Literature review

Safe training on-board

The science behind AR shows that it can make training interactive, more productive and gratifying. Several studies have shown that AR systems can provide motivating, entertaining, and engaging environments conducive for learning (Lee, 2012). Thus, AR is capable to enhance currently used media in training such as booklets, posters and videos. By virtue of such a rich training content, assisted with AR tools, the owners of shipping companies can boost the effectiveness of on-board training. Seafarers hold a high standard of expertise in their profession, where specific knowledge and skills are required to operate this sea bound mode of transportation (Albayrak and Ziarati, 2010). A good quality training is required to ensure that a vessel maintains a high standard of operation (Dragomir and Utureanu, 2016). Similar views are pro-posed by Bârsan et al. (2012) of having well-trained seafarers as being essential to any maritime company that wishes to demonstrate their responsibility, while at the same time to be perceived by the industry as of having a high quality and competitive operation. There have been numerous changes in methods of maritime training over the last two decades. With the assistance of modern technology, several companies provide innovative software solutions for on-board training. Maritime Education and Training (MET) has used Computer-Based Training (CBT) as an asset to achieve its training objectives (Triand Maritime, 2018).

Augmented reality as a training tool

Advanced technologies always play a significant role in the education system, since they offer better opportunities for creating interactive, personalised learning materials and activities that are compliant with the specific needs and characteristics of learners (Kiryakova et al., 2018). AR for training and education can be highly effective, time-efficient and guaran-tees that trainees acquire the necessary skills (Ferrati et al., 2019). Furthermore, it welcomes trainee's and students' feedback, alerts the trainee, provides instructions and different levels of guidance which are key for the learning process. AR training can combine real experiences with virtual instruction and guidance. Existing studies which applied AR in Chemistry classes by using AR applications managed to gain higher levels of student engagement in the classroom (Chen and Liu, 2020). Moreover, in an experimental study of physics teaching to students, the findings suggest that the learning experience of the students is better when it is enhanced with AR technology (Thees et al., 2020).

AR has dramatically shifted the location and timing of education and training (Lee, 2012). In AR, the environment is real, but extended with information and imagery from the system. In other words, as Chang et al. (2010) and Lee (2012) argue, AR bridges the gap between reality and the virtual environment in a seamless way. Moreover, by using AR in higher education even students' attitude is improved as student seem to have a stronger motivation for learning while their academic performance is much improved (Martín-Gutiérrez et al., 2015). There is also an evident potential for AR to provide helpful contextual, on-site learning experiences and serendipitous exploration and discovery of the connected nature of information in the real world (Lee, 2012). Therefore, AR not only has the power to engage a learner in a variety of interactive ways, that have never been possible before, but can also provide to each individual their own unique discovery path, containing rich content from computer-generated three-dimensional environments and models.

Augmented reality in the shipping industry

Digitalisation and new technologies are transforming the shipping industry, because they provide efficiency and flexibility. One of these technologies is the AR which can be used for many different tasks such as navigation, engineering and simplifying inspections. In navigation, AR can provide to the navigator a direct view of the ship's movement and a path with the current rudder position and speed orders. Digital information projected to head-glasses is appealing, as most information is available and collected into one system, thus allowing the bridge team to spend more time looking out of the window than down into the bridge's scattered resources. The implementation also encompasses areas of conservation, like marine protected and environmentally sensitive areas (Procee et al., 2017). In the engine room of a ship, the engineers can wear the head-glasses with which the virtual information about an equipment combined with the real environment, may aid engineers to view both the virtual information and the real equipment operational efficiency while controlling the virtual data through their sight, gestures and voice. They can receive additional three-dimensional information when it comes to repairing equipment or even to diagnose and solve a mechanical issue. Apart from the real environment, engineers will be capable to inspect animated components regarding the part which needs to be replaced and the tools to be used, while an audio instructor may guide them through each of the steps via the integrated speakers with head-glasses. The virtual process of disassembling is available through the head-glasses at anyplace, anytime (Ari, 2018).

Materials and Methods

The current study explores the development of AR technology on-board ship operations and on maritime personnel training. In this qualitative research, the use of inter-views was implemented to gather fresh insights about the implementation of AR as the topic is new and on a very early stage of development, interviews were required for in-depth research aiming better explanation of the phenomenon and higher validity of the findings. The 'interpretivism' approach as a school of thought concentrates on the meaning of social interactions. Interpretivism guided our qualitative approach through which researchers and interviewees interpret and discuss in-depth their experiences and the environment in which they live (Thanh and Thanh, 2015). Qualitative interviewing, using semi-structured questions, makes use of open-ended questions to encourage meaningful responses (Patton, 1990). Moreover, by conducting semi-structured inter-views there is a clear focus on the research topic and the aspects to be discussed with-out compromising the freedom of the interviewee to elaborate on issues and aspects relevant to him/her.

In the semi-structured interviews, there was a list of themes and questions to be covered, although these may vary from interview to interview (Adam, 2018). This means that some interviews had to be adapted aiming to give a specific organisational context that relates to the research topic. This depends on the knowledge about AR and the background of the interviewee i.e. if the interviewee is a shipowner, captain, engineer, investor or director of a related shipping company (*Table 1* and *Figure 1*). The order of questions also varied depending on the flow of the conversation. On top, confirmatory questions were sometimes required to guarantee the under-standing of the meanings and the variation of events within particular organisations. Data were audio recorded during the interviews as long as participants agreed to be recorded.

Table 1. *Profile of interviewees.*

Company	Job title	Years of experience
Shipping Management Company 600 vessels, 20000 employees	IT manager	5
VR training provider Runninf in 1000 vessels	CEO, E. Captain	12
LNG Shipping Management Company 31 LNG vessels	3rd officer	7
Shipping Management Company	1st engineer	15

600 vessels, 20000 employees		
Family Shipping Management Company 10 vessels	IT Manager	27
Shipping Management Company Tankers & Bul Carries 21 vessels	Health Safety Quality Manager	25
Shipping Management Company 600 vessels, 20000 employees	Fleet Manager	25
Shipping Management Company 70 owned vessels, 100 on a crew management	Captain/Head of Training Department	23
The biggest industry e-learning provider More than 10000 vessels	Business Development Manager	10
Leading provider of global marine support services. Network of over 44000 seafarers.	HSEQ & Marine Superintendent	20
LNG Shipping Management Company 16 LNG vessels	Chief Officer, Onboard Trainer	10
International provider in maritime electronics equipment	Chief Engineer-Area Sales Manager	6
Training of seagoing personnel, Safety & Quality assurance, Crewing and incident investigation	HSEQ & Marine Trainer, consultant	32
Shipping Management Company 400 vessels, 15000 employees	Master Mariner (Oil, Chem and Gas)-Pilot-QSHE-Maritme-Crewing-Training	26
Training solutions for maritmie security services for oil & gas employees	Training Development Manager	13
Crew Management company with worldwide network of offices and training centres. 13000 crew onboard	Crew Training Manager	30
LNG Shipping Management Comapny 31 LNG vessels	3rd Officer	5
Crew Management company with worldwide network of offices and training centres. 11000 crew onboard	Global HSEQ Manager	22
Shipping Management Company 100 vessels, 4000 employees	Group Fleet Personnel Manager	30
Shipping Management Company 50 shore-based & 700 seafarers	HSE Manager	15
Shipping Management Company 100 vessels	Seafarer	4
Shipping Management Company 14 vessels	2nd Officer	10
Mechanical & Industrial marine engineering 19000 employees, 200 locauons, 80 countries	Technical Expert	12
Crew Competence Digital Management Solution Training, E-Learning, ECDIS, Maritime Training, Human-Resource, E-Assessment, E-Certification, ETC training centre, Shipping Ondustry, Crewing	Product Manager	12

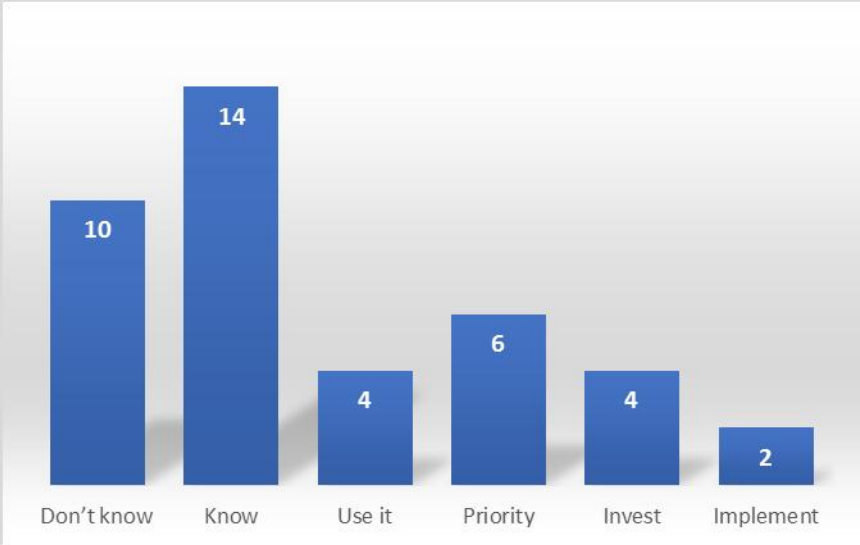

Figure 1. *Participants' prior knowledge about AR.*

The twenty interview questions were divided in two parts. The first part concerned on-board training and the second part addressed the use of digital technologies and AR implementation. In the second part, interviewees listened carefully to the presentation of AR, they asked questions, made suggestions and finally expressed their opinions in the form of feedback. The authors have significant experience in the development of new technologies and products. The current study sets the ground for a long-term plan to break down the complexity of this innovative and complex idea (the use of AR for on-board training) into easy to comprehend ideas and thereby increasing its efficiency and functionality. Qualitative data analysis approach relies on the processes and procedures that are used to analyse the data and provide some level of explanation, understanding, or interpretation (Berg and Lune, 2016). The purpose of our analysis was to become familiar with the data, to identify the meaning and determine which pieces of data should be kept. Then, we grouped into themes relevant data and created a framework. As such, we identified patterns, we made connections, we identified relationships between themes or data sets, we interpreted data and explained in-depth the findings (Genc, 2019). Finally, the authors developed a mapping and interpretation, involving the analysis of the key characteristics as these are depicted in the Figures.

Analysis began early and simultaneously with the data collection in order to improve the interview guide (Charmaz, 2011). Audio records from interviews were transcribed and then edited with the use of NVIVO 12. Thematic analysis enabled the reduction of the amount of collected data by considering only data from specific sub-themes rather than all possible cases or elements (Saunders et al., 2009). The interviewee sample was taken from a range of viewpoints and job roles from the shipping industry (10 from shipping companies' offices, 6 active seafarers, 6 provider companies and 2 training companies). The participants' profile is outlined in *Table 1*. Reliability and validity are two factors which we, as qualitative researchers, considered while we were designing the study, analysing results, and evaluating the quality of the research (Suri, 2011). To improve the internal validity of the research, only the most appropriate interviewees from different companies and positions of the shipping industry were considered. Finally, we finalised the data collection pro-cess when data saturation was reached meaning, data saturation determined how many interviews were enough to acquire rich and thick data (Dibley, 2011). This was reached when no new information was emerging from the data (Guest et al., 2006).

Results and Discussion

Most of the interviewees described virtually the same process for on-board training. Variations were found though, depending on the size of the shipping company, the vessel type and class. The main similarity in on-board training, across the board, was that seafarers don't have time for on-board training. Familiarisation processes take up to 3 hours maximum. Emergency drills done on weekends and computer-based training were noted as the most tedious aspects of the training process. Successful training that has a major impact on the safety on-board ship relates to the qualifications and responsibility of the Second Officer that carries out the training on-board. It has been clear that in shipping there is no consensus on the use of technology in on-board training. Half of the respondents believe, trust and use technology while the other half are sceptical of its benefits, especially when related to the expense that such technology entails. AR technology is very new, not only for the shipping industry but other industries and also for the public. The attractiveness of AR lead to technological and academic proponents to continuously raise expectations, to come up with new ideas, which sometimes sound like science fiction. However, nowadays, the technology required for AR applications has matured and, as a consequence, the number of commercial AR applications and especially consumer AR applications is growing exponentially. When considering AR and on-board training today, research findings deliver the following pros and cons;

Advantages of AR

The interviewees argue that implementing AR in on-board training would bring only slight benefits. Only three out of twenty-four said that AR would be helpful in the improvement of training. Two interviewees have used AR and know what it is. This shows that the majority of the industry do not yet see any actual benefit from the use of AR in on-board training. As such, AR technology is not a priority for the time being (*Figure 2*).

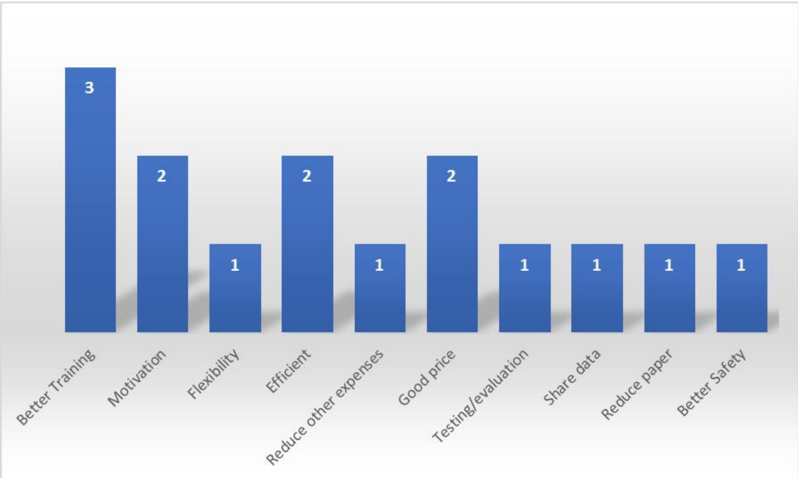

Figure 2. *Advantages from the potential implementation of AR.*

Disadvantages of AR

The biggest concern about AR usage is the price. The respondents argue that AR would not be of any use for on-board training. They feel that it is a very complex technology and distracting to use. They view it as inefficient, along with the concern that it would be both difficult and expensive to develop an AR application that could be universally used for any vessel type (*Figure 3*).

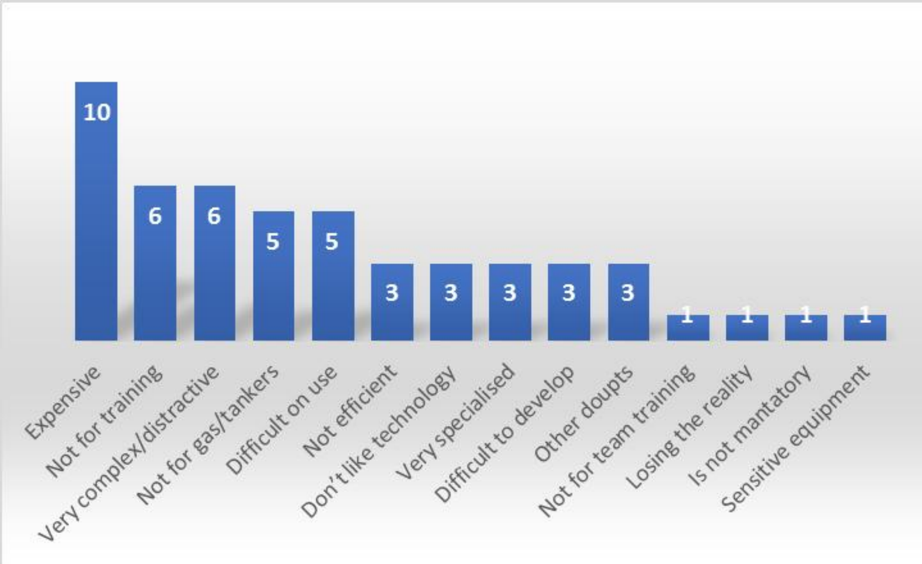

Figure 3. *Disadvantages from the potential implementation of AR.*

Major concerns about digitalisation and new technologies

For shipping companies, due to the narrow profit margins, the major concern is cost. Business developers believe that an investment in new technologies must have a significant return of their investment in both money and time. Seafarers, on the other hand, argue that they are already using effective training methods. The overwhelming majority of seafarers hold the view that there is simply not enough time on-board for training, with seafarer's days being dominated by work, they don't want any more training, especially via technology. The last factor, but not the least, is the nature of the on-board environment. Tankers and gas carriers cannot use any electronic device outdoors, due to strict rules of safety. Bulk carriers, which are cheaper vessels, do not use as much as tankers and gas carrier's high technology to enhance their performance. Finally, the environment on-board (bad weather, saline humidity and dangerous structural setting of a ship) makes the implementation of any electronic device extremely difficult.

The current study explores the application of learning technologies by expanding further the existing literature which supports the usage of learning technology in contrast to didactic styles (Saunders and Gale, 2012). Our findings suggest that there is a need for AR technology on shipboard operations but, not for additional on-board training. This is due to the fact that the shipping companies are physically training seafarers before taking them on-board. The manning standards of ships are leaning toward employing fewer and fewer crew on-board, therefore there is now less time for the crew to train. For this reason, advanced training technologies, implemented with simulators and VR technology, stands to give the seafarers a decent and proficient training experience. Likewise, the Maritime Labour Convention (MLC) (2006) utilises the time from resting hours of seafarers for drills. Under these circumstances, the MLC shall take training more seriously by considering training time the same as working time, so seafarers can give the correct attention to training. Interviewees that were close to technology, and understood AR, argue that an AR solution is more appropriate for shipboard operations and not for training. AR has a great potential to help in maintenance, remote assistance, machinery diagnostics, work tasks, work checklists and finally exporting reports in PDF form or video.

Interviewees highlighted that, one of the biggest challenges which the industry is facing is the familiarisation of staff with new technologically advanced equipment previously unknown to operators and to seafarers. As such, there is a need for training in the use of this new equipment and machinery and this is the challenge which AR may address. We propose an integration of sensational pedagogy with training (Gallagher et al., 2017) aiming to aid the on-board crew to visualize processes and concepts resulting to learn in depth (Ruiz-Primo et al., 2011). Sensational pedagogies enforce higher learners' engagement with the learning material in comparison with the one-way communication teaching (Gallagher et al., 2017) which will lead to deep learning. While, marine equipment is traditionally large, cumbersome and extremely technologically complex (Millar, 2006) also differs from vessel to vessel, while engineers have to move from vessel to vessel whereas, they need to familiarise with the equipment. As such, our study proposes that AR is not only a matter of efficiency but also a matter of safety via horizontal communication as for example it is argued by Fei (2011) that trust and understanding is built between seafarers and on shore managers.

Contrary to the existing literature review which describes the perspective of AR in training, our findings suggest that there is much more potential for the AR tool and this format of AR is welcomed by the market. For instance, a 3D model of the vessel can be uploaded to the AR device, and by using the glasses the seafarer can 'see' behind bulkheads and/or underfoot. Every pipeline will be displayed to the seafarer for what it is and also request guides for specific processes or controls. In the engine room the engineer can see 'inside' the machinery and make a diagnosis of a potential problem by following steps and filling in the relevant checklist. A video recording can be made of the procedure and can be sent to the manufacturer. Similarly, a faulty part on machinery can be changed on-site with remote assistance from the manufacturer in real-time, thus eliminating the costly presence of a service engineer.

Everything can be controlled and checked easier and faster, reducing costs, paper usage and time. Checklists can be completed via AR smart glasses for every task and can instantly upload the information to a cloud. As such, all parties concerned, on-board and onshore will be informed about any work that will be done on-board. Companies' training costs are high, especially if manufacturers visit them on-board. However, with AR smart glasses, training can be done remotely in real-time with a connection to the manufacturing company. This solution, enables the development of new technologies over time as Mazzarino and Maggi (2000) concluded in their research that 'it must be stressed that new technologies will produce an increased integration, interoperability and intermobility'. AR smart glasses are the extension of the land offices' eyes. Staff at the land offices (i.e. IT, trainers and managers) can connect in real-time with the vessel anywhere in the world. Nowadays, offices support the vessel not only by phone, but with real-time eye contact. Using the AR remote assistant smart glasses in this way saves both time and expense.

AR smart glasses can be an innovative communication channel through which the vessel will be connected with the land (land office, manufacturers, providers, etc.). Moreover, AR can bring vessels one step closer to autonomy. In the near future, machines and equipment will communicate and exchange data via internet networks. AR smart glasses will be the primary tool which will receive and send informative data for the operator. Other software which can connect with the glasses are digital maps (i.e. ECDIS). Integrated displays on the bridge have relative advantages over scattered displays (Sauer et al., 2003). By taking these into consideration we can appreciate the benefits of having all the information in front of the eyes of the navigational officer with the AR smart glasses, enhancing situation awareness (SA). By using Artificial Intelligence (AI), the AR smart glasses can be utilised as the receiver of data, recorder of data, and as an exporter of newly analysed information based on AI to assist in better decision making. Even in cases where unmanned vessels will dominate the seas, as it is expected to happen in the following 15 to 20 years, sailors will be less but more vital (Jo and D'agostini, 2020). Therefore, any additional help provided by technology to the crew will be helpful and valuable.

Conclusion

The digital revolution is shaping not only shipping but our everyday life. AR is capable to transform the shipping industry, and there are already a few obvious applications for it in training with the creation of real-world cases and skills development. Applications, too, can be envisioned in maintenance by providing engine diagnostic information and remote support to engineers at sea. AR technology can also provide improved situational awareness and decision-making support for operations. Moreover, this research argues that AR is not appropriate for training on-board but can be a powerful tool for the engine room: offering guided maintenance and/or assistance for machinery with steps and tasks, check-list control, inspections and training in advanced technology equipment. Engineers need to have a tool which enables training on new equipment, manages maintenance and has remote assistance with the provider on land. This tool can be the AR headset. AR technology can guide the engineers and train them: while engineers will be looking at the equipment AR will be adding the crucial information in digital format and it will also complete the checklist and any inspection.

The industry is based 100% on the human factor along with low profit margins and constant efforts to increase these by reducing costs. It is clear that ship-owners are financially orientated and cost-driven making every new investment of theirs to be affected by profitability and the requirements of current legislations. It is also widely recognised that the future is going to be even more digital. However, in shipping, new technologies have always been regarded with some scepticism. The shipping industry has a traditional, more conservative approach to the operation of ships.

Further research is strongly recommended on the necessity of integrating AR technology with appropriate bridge equipment and machinery. AR technology, can enhance the interaction of the crew with operations and maintenance. Radars, AIS, ECDIS, main and auxiliary machinery, can all be integrated with AR technology. What remains to be discovered is how AR affects shipboard operations and the needs of shipping companies. Most of the interviewees were unaware of AR technology and its usability (as stated in *Figure 1*). Half of them were not supporters of technology and any of the new tools that it brings. It is recommended that an experiment should be carried out which will test a prototype AR application. An AR headset would add value to the experiment, giving a more realistic approach with participants. To test the validity of the research, it is recommended that an additional survey should be conducted.

Furthermore, the research was based mainly on 2 countries: Cyprus and Greece. Countries from Northern Europe and other continents may well produce different results. Future research may also need to consider how AR applications could be used for onboard operations and in industry in general. The impact of sales and revenue for providers, the added value and customer satisfaction for all the users should also be thoroughly researched. How all necessary information will appear in an AR headset, how the headset will be designed and how easily it can be adopted by seafarers, shows the way for future research.

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Conflict of interest

Authors confirm there are no conflict of interest with any parties involve in this research study.

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