Simulation technologies of virtual reality usage in the training of future ship navigators

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Abstract. *Research goal*: the research is aimed at the theoretical substantiation of the application of virtual reality technology simulators and their features in higher maritime educational institutions. *Research objectives*: to determine the role and place of simulation technology in the educational process in the training of future ship navigators in order to form the professional competence of navigation. *Object of research:* professional training of future ship navigators in higher maritime educational institutions. *Subject of research*: simulation technologies of virtual reality as a component of the educational process at higher educational maritime establishments. *Research methods used*: theoretical methods containing the analysis of scientific sources; empirical methods involving study and observation of the educational process. *Research results*: the analysis of scientific publications allows to define the concept of virtual reality simulators, their application in the training of future navigators, their use for assessing the acquired professional competence of navigation. *Main conclusions*: introduction of simulation technologies of virtual reality in the educational process in higher maritime educational institutions increases the efficiency of education, promotes the development of professional thinking of students, enhances the quality of professional competence development.

Keywords: professional training of ship navigators, simulator training, simulation technology, simulators, virtual reality.

1 Introduction

1.1 The problem statement

Ensuring the development of the professional competence of future navigators should take place in accordance with the requirements of the International Maritime Organization (IMO), which defined the training and introduced it into the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers with the Manila Amendments of 2010 [10]. The STCW Convention defines the operational requirements for a number of simulators that are used in the process of developing the professional competencies of future marine specialists, and for the first time in international regulatory practice the assessment of professional competencies by simulators has been introduced. The normative document defines the operational requirements for a number of simulators and for the first time in the international normative practice training and assessment of competencies with simulators has been introduced.

World practice shows that in connection with the development of digital technologies, designing and creating software products is the most effective tools of professional training of ship navigators, which are simulators of the modern generation using virtual and augmented reality (VR and AR). Such simulators allow to bring the training conditions to the conditions of the reality for the ship navigators when navigating the vessel, and navigational simulators to a large extent ensure fulfillment of psychological and didactic requirements to the process of skills and abilities formation.

1.2 Theoretical background

In the context of our research, we analyzed the current vision of the role and place of VR simulators in the professional scientific discourse from the standpoint of taking into account the specifics of the subject field of professional activity of future marine specialists.

VR simulators are quite widely used in the training of students of maritime professions all over the world. Ukraine has no deep experience in the use of simulation technologies in the higher maritime education system, and therefore the approval in 2018 of a new standard of higher maritime education for the first (Bachelor level), aimed at developing competencies of the XXI century [10] has set the benchmarks for changing the educational paradigm for optimization and practical training process, integration of training in the educational process in order to effectively form the professional competencies of future marine specialists.

Among the works devoted to training and practical training of cadets in marine schools should be identified works of Asghar Ali [1], Djelloul Bouras [6] , Olle Lindmark [15], Charlott Sellberg [30].

Olle Lindmark, studying simulators in maritime education, noted that in 1994, the IMO created a simulator working group that was created to structure training information for inclusion in the STCW, and this group identified the simulation as “realistic simulation”, in real time, any handling of a ship, radar and navigation, propellant, cargo/ballast or other ship system, including an interface suitable for interactive use by a student or candidate both within and outside the operating environment. Higher, and compliance with the standards set out in the relevant sections of this section of the STCW Code [15].

Yaser H. Sendi classifies simulators on real, virtual and constructive, and determines that the constructive ones contain a virtual reality and is the highest level of complexity of simulators for the formation of professional competencies and their evaluation [31].

Constructive simulators – held in a virtual reality environment, it is considered a very complex level of simulators for the purposes of allowing instructors (i.e. captains) to analyze the performance of apprentices and evaluate their master of skills after using the simulation.

VR simulation technologies are new forms of professional competence development for marine specialists who, through the creation of quasi-professional situations, can form professional thinking and develop the necessary skills without risk to life and save time and resources. But it should be borne in mind that in most marine higher educational establishments of Ukraine, traditional approaches to teaching still prevail, therefore, a promising direction for improving the educational process in maritime institutions of higher education is the creation of simulation (training) centers in order to systematically approach the formation of professional competencies.

In the NMC Horizon project, VR technologies are part of the promising direction of the tools and processes of visual imaging technology that are used to combine the efforts of the brain's ability to quickly process visual information and to find order in difficult situations. Visualization technologies are used to improve teaching, learning, creative search and have a great prospect of use and effectiveness in the future [23]

Introduction of the concept of “Virtual University”, which represents the use of modern development platforms virtual reality, takes place in the experimental process by industry in many authoritative implementations such as Massachusetts Institute of Technology, Yale University, Lund University, IBM, Microsoft.

Submitted by various researchers, the generalized results of the use of simulators with VR in the systems of training specialists of different directions can make a reasonable opinion on the feasibility of using VR technology in the system of training future mariners, taking into account the peculiarities of the organization of educational process in higher maritime educational institutions and the specifics of professional maritime activity sailors merchant fleet.

1.3 The objective of the study

The purpose of the article is to substantiate the essence of simulation technologies of the VR used in the process of training of marine specialists, and to determine the specifics of the application of simulation technologies of VR in the formation of professional competencies of future marine specialists.

2 Results and discussion

The use of e-learning is based on and used in the learning process of virtual environments [5; 18; 24], complemented by the reality of computer simulations, virtual 3D worlds with the effect of immersion. According to the numerous studies

[11; 12; 14; 19; 25; 35; 44], the virtual environment is a quality educational tool, and the task of the teacher is to reorient modern virtual technologies to learning.

Virtual reality (VR) and augmented reality (AR) represent a new direction in the development of information technology. VR and AR are two closely related technologies that have certain differences.

VR is a similitude of the real world created by technical tools in digital form. The created effects through the projection onto the human eyes and cause the feeling that they are as close as possible to the real ones.

VR allows users to immerse themselves in the world created by the computer, and get the sensory experience there. Augmented reality (AR) is an image that is imposed on objects of the real world. Augmented reality is characterized by the inclusion of digital information (images, video and audio) in real space, trying to combine reality with the virtual environment, allowing users to interact with both physical and digital objects [7; 9; 13; 16; 17; 21; 22; 26; 28; 32; 33; 36; 39; 41; 45].

Consumer Technology Association at CTA-2069 standard highlights the mixed reality (MR), a seamless combination of the real environment and digital content, where both environment exists to create experience [27].

Virtual technologies for educational purposes began to be used as early as in the 1960s as airplane simulators [38], and in the 80s, in the form of systems for dialogue management with machine-generating images [42].

The most common means of immersion in VR are specialized helmets / glasses, the display of which outputs 3D video, and the sensors capture the head turns and change the image on the display.

From the point of view of cybernetics, the essence of virtual reality is reduced to the following characteristics: 1) creating means of programming three-dimensional images of objects that are as close as possible to real, models of real objects, like holographic; 2) the possibility of animation; 3) network data processing, which occurs in real time; 4) creation of means of programming of the effect of presence [29].

Today, using a web browser or smartphone, it’s possible to switch from the Amazon to the library (Google), to your personal space (Facebook). There are virtual spaces for meetings (Skype) and even game arenas (Steam Valve) as teleportation in the digital sense. But none of these services will be able to simulate the real world due to limitations of 2D screens.

Many VR technologies are just 360-videos, which format provides a sense of presence: the one who browses himself chooses, where to look, exploring the space, and is an active participant in everything that’s happening. Immersion is achieved even in the absence of a screen frame, through which so everyone is accustomed to watch the news, reality show. Video review of VR requires photorealistic and real-time environments to create unity with the browser and presence phenomenon and joining the situation.

There are many classifications of virtual simulators using a variety of criteria, such as the degree of realism, hardware, the scale of the virtual space that is being created.

The advantages of virtual simulators are:

- the possibility of creating a safe for the student working space in which he can work out various skills without risk for his life;
- the creation of an educational space, built on the needs of those who study;
- the possibility of repeated repetition to achieve automatism;
- compatible scenarios and actions;
- the possibility of immersion in a situation in which it is necessary to quickly make decisions and act [37].

Also, the advantages of using simulators and virtual simulators include the possibility of using them for both individual work of the student and for organization of group training.

For the first time simulations and virtual simulators began to be used in medicine.

A virtual simulator is a modern learning tool that provides a clear idea of the object of the research and work with it without direct contact with the object [30].

A virtual simulator can be defined as an interactive component of e-learning to study and consolidate a variety of practical skills when working with real objects in the subject area.

There are three types of VR simulators:

1. Those which teach (electronic textbooks).
2. Those which control (testing systems).
3. Those which teach skills (multimedia and / or animated simulators of reality with subjects of the subject area).

The first simulators were similar to computer classes, where simulation of situations took place, but the lack of them was an unnatural presentation of objects. Ideal simulators are those that combine ("mix") the real and virtual world and where the visual series is almost entirely true reality. These simulators completely allow you to work out scenarios of real professional situations in a completely realistic three-dimensional space.

Virtual simulators can be used primarily where it is necessary to work out the sequence of actions, as well as the formation of sustainable skills for the prevention and elimination of emergencies, accidents.

The virtual training complex significantly reduces the operating load on a real object (vessel element), reduces the probability of errors, increases the inter-repair resource. The main advantage of virtual simulators is that for a minimum amount of time the student receives a maximum of practical experience.

In the traditional scheme of training, students receive profound knowledge only from individual disciplines, and combining this knowledge in practice is given the opportunity only after several years of work as a responsible decision-maker, virtual simulators give the opportunity to feel like a person directly in the learning process of certain scenarios [8].

There is a phenomenon of kinetheus in the VR – the indicators of the vestibular apparatus and organs of sensation are different, because a person sees movement, but the body remains at rest. The brain perceives visual information as hallucination, which may be felt by poisoning, and nausea occurs. Similar feelings also exist when creating the effect of staying at sea. The effect of the sea sickness is very similar to the real feelings, getting used to it can even help future carriers in future work

An important element in achieving the effect of a psychological presence is theory of embodied cognition [40], which explains the fact that people are better at perceiving information when acting, rather than when they are watching what others do or listening to or reading about it [4].

That is, in fact, the main purpose of the use of VR simulators is to provide the new quality of professional training of future specialists by immersing the students in the real atmosphere of solving quasi-professional tasks, optimal for the formation of professional competencies and personal qualities of future professionals in conditions that are as close as possible to the conditions of future professional activity.

For the first time marine simulators were used in Sweden in 1967 (Goteborg) with a research purpose to analyze the prediction of the behavior of the crew [6].

Today, the traditional training of sailors has changed the emphasis on practical orientation and the use of simulators for the formation of professional competencies without the need to be on the vessel [43].

Simulation technology in a navigational system is a modern technology of training, assessment of practical knowledge, skills based on the use of computer models of navigation processes that are as close as possible to the conditions, simulation of communication interaction in specific situations.

The pedagogical advantage of using simulators in maritime education is that it is possible to develop such scenarios or exercises that are designed to study and evaluate specific learning outcomes [30].

The use of training technology in the educational process allows you to work out the interaction of the crew with each other and with other participants in the navigation; to simulate emergency and crisis situations; to check psychological readiness of cadets for actions in extreme conditions; reduce the risk of making wrong decisions, etc. [2].

Charlott Sellberg [30] in her doctoral thesis experimentally proves that work on simulators meets the requirements of STCW, and all training in these simulators contributes to the formation of professional competencies of marine specialists.

Kherson State Maritime Academy has the experience of implementing the model of a competent approach to training according to the program of experimental activity on the topic “Theoretical and methodical principles of implementation of the competence approach in the system of graduation of maritime industry specialists training” in accordance with the order of the Ministry of Education and Science of Ukraine No. 1148 dated October 7, 2014.

In order to systematically approach the development of professional competencies of marine specialists and through the support of partner companies and central and local authorities, a training complex (simulation center) was opened in October 2016, which included 19 laboratories, 16 simulators and 21 training room.

All these laboratories, training bases and complexes were combined into a single training complex, which was named “Virtual-Real Ship”. Several dozen cadets have the opportunity to simultaneously undergo training on such a vessel, and the preparation itself is carried out not only in conditions that are as close as possible to the real, but also in the conditions of direct bearing of the ship's watch.

KSMA "Virtual-Real Ship" is a separate structural innovation unit in the education system – a full-fledged simulation vessel – combining educational continuity between the pre-practical and practical stages of training and is a powerful tool for building the professional competencies of future marine specialists. Thus, in the center, the development and implementation of methodological and normative provision of the educational process, the formation of an individual educational trajectory, standardization of criteria for assessing knowledge, skills, competencies, and high-tech emergency response standards that meet the requirements of the STCW are being developed.

All simulators meet the requirements of international and national standards and regulations (including STCW, SOLAS, IMO model courses), as well as certificates of leading classification societies. They provide effective training and assessment of professional competencies of the cadet, which corresponds to the concept of evidence-based competence in the marine industry in accordance with the requirements of the STCW.

Educational training on "Virtual-Real Ship" is carried out in two directions:

- professional training with the priority of special professional knowledge;
- sequence of actions and group training with an emphasis on the human factor-coordination of teamwork and resource management in crisis situations.

In the educational process of the KSMA simulation complexes, VR simulators are used, on the basis of which educational programs are implemented. The appropriate platform, thanks to realistic interactive scenarios and opportunities for immersion, provides the following capabilities: acquisition of knowledge and skills with sophisticated techniques, gaining knowledge about reducing the probability of occurrence of extraordinary situations, getting experience of troubleshooting and restoring normal working conditions in the event of an emergency situation.

The purpose of training in VR simulators is:

1. Acquisition, improvement and practical use of the acquired skills of navigation
2. Formation of professional thinking, reflection of their activities.
3. Practical understanding of their role in the team.

So, in the KSMA there are two laboratories with VR simulators (Fig. 1):

- Full-function navigational bridge;
- Full-function simulator of a vessel with a dynamic positioning system.

The scheme (Fig. 2) defines professional competencies according to the STCW, which are formed in these laboratories.

Teachers of special professional disciplines develop exercises on simulators that must be performed by students in accordance with the program of discipline and define their goals according to the general objectives of the training defined for the particular discipline. Training objectives, simulators, tasks and evaluation criteria are described and defined in accordance with the requirements of the STCW [10]. Before approving by the corresponding heads of the department, exercises on the simulators are tested by instructors in order to ensure that they are consistent with the objectives of training. Instructors familiarize students with a simulator before undertaking any exercise, including goals, tasks to be performed, assessment criteria, and arrange a discussion session after completing the exercise, in which the instructor and students discussed the exercise and its outcome. During the exercise on the simulator, the instructors evaluate students' activities [34].

Fig. 1. Full-function navigational bridge

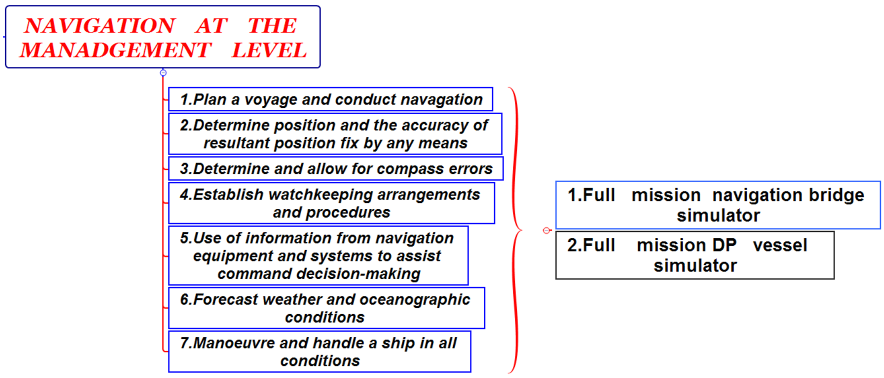

Fig. 2. VR laboratories of KSMA

Training laboratory “Full-function navigational bridge” is equipped with a simulation of the navigating vessel with a circular visualization of the navigational environment with an angle of the visible horizon of 210 degrees horizontally and 35 degrees vertically, a simulator of the integrated navigation system with two ARPA stations, two ECDIS stations, software and hardware controls a vessel, a sound simulation system, means for controlling and monitoring a marine propulsion system, an imitation of a maritime system. The training laboratory “Full-function navigational bridge” meets the requirements for the A1-grade classes in the DNV/IMO classification.

The algorithm of the simulator though similar to modern computer games, which consist of passing of missions (tasks), but unlike them, there are no levels of complexity – the simulation always occurs in the mode of maximum realism.

The purpose and tasks of training on this simulator, as defined in the model course 1.22, is to gain experience in working with ships in different conditions and to make a more efficient contribution to the bridge crew when maneuvering ships in normal and emergency situations.

In particular, the aim of the course is to acquire the following competencies:

- familiarization with the use of engines and steering for maneuvering vessels;
- understanding of the effects of wind on vessel behavior, shallow water flow, shallow, narrow channels, and loading conditions;
- a deeper understanding of the importance of planning a transition or maneuver and the need for an alternative plan;
- a deeper understanding and awareness of the effective procedure for bridge and crew work during the navigational watch, in normal and emergency situations;
- a deeper understanding and understanding of high-quality interactive communication and the benefits of creating a common mental model for a planned transition.

The results of training are written in specific skills, which after the completion of the course will be able to perform the cadets:

- Form a bridge team, using all available resources, enforcing official responsibilities and creating a sense of responsibility for all crew members
- Make a detailed plan for the transition and track the progress of the vessel in accordance with the plan
- Assess the situation and make decisions to ensure the safety of the ship
- Support pilots and track their actions:
- Determine the need for a contingency plan in a high-risk area
- Recognize the sequence of actions leading to an error and effectively interrupt such sequence
- Interpret and effectively use data on maneuvering the vessel.

In the course of an experimental work, the training was integrated into the curriculum of bachelors and masters. Thus, in the laboratory there are practical classes in the disciplines “Ship management” and “International rules for preventing collisions of ships at sea". The distribution of hours into lectures and practical works (Table 1) indicates that 48.6% of hours and 41% of the hours have been allocated for practical training.

Table 1. Division of hours into lectural and practical ones.

1. Ship Management					
Course	**II**		**III**	**IV**	**Total**
Semesters	3	4	6	8	
Lectures	20	20	18	16	74
Practical works	16	20	18	16	70
2. International rules for preventing collisions of ships at sea					
Lectures	–	–	–	20	20
Practical works	–	14	–	-	14

The STCW [10] defines minimum requirements for the content, criteria and assessment of professional competencies, which should be more clearly specified by each higher education institution on its own.

Teachers have developed working programs of disciplines that contain requirements for the formation of professional competencies, methods of demonstrating competencies. Thus, in Table 2, the competence requirements for skills of the specialists from the work program "International rules for preventing collision of ships at sea" are presented, which meets the standards of the Ministry of Education and Science of Ukraine, requirements of section AI/12 , Section BI/12 of SNCW and IMO Model Course 1.07, "Radar Observation and Planning and Operational Use of Automatic Radar Plotting Aids" (ARPA).

Table 2. Competency requirements for the skills of specialists in the working program of discipline.

Competence	**Skills**	**Methods of competency demonstration**
Maintain a safe navigational watch	*Watchkeeping* Thorough knowledge of the content, application and intent of the International Regulations for Preventing Collisions at Sea, 1972, as amended. Thorough knowledge of the Principles to be observed in keeping a navigational watch.	Evaluation of radar simulator and ARPA results, and work experience

Framework of competencies is also used on the LMS Moodle electronic platform, which allows you to retrieve individual trajectories and form professional competencies [20].

The training takes place in small groups (4-5 cadets), which allows each cadet to actively participate in the educational process, demonstrate their knowledge and acquired competencies. A permanent working relationship is formed between a teacher and a cadet, resulting in a significant increase in the degree of mastery of both theoretical and practical knowledge [3].

Stages of classes consist of the following stages:

- Training (briefing), which assesses the situation, equipment, determines the object and purpose.
- Simulation process itself, in which an important condition is the maximum sense of the reality of the situation.
- Summaries, analysis (debriefing).

Successful formation of professional competence is considered when the cadet reaches certain set of points. The level of competence development can be evaluated automatically by special software, and the assessment of the teacher-instructor who has the appropriate certificates of permission rating-by average (execution time, accuracy, absence of errors) is possible.

When comparing grades for discipline in 2018, until the introduction of integrated training plans between the training center and academy, and in 2019, there is a significant improvement in the quality of knowledge of students, which indicates the effectiveness of the use of technology VR in the educational process in the training of marine specialists to improve the quality of the formation of professional competencies (Fig. 3).

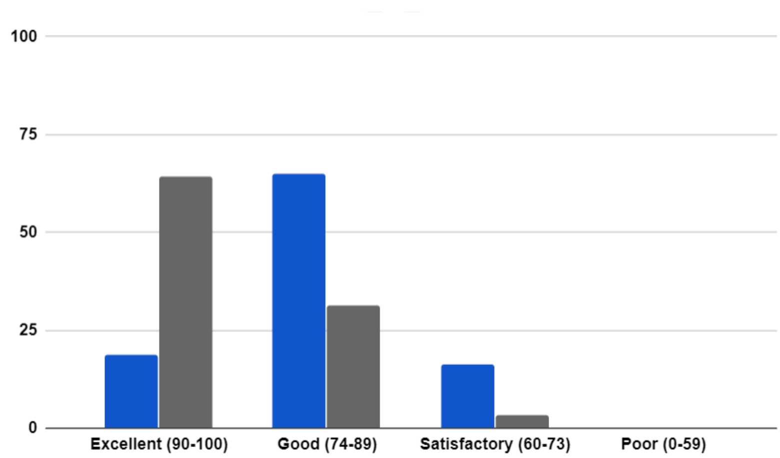

Fig. 3. Comparative chart of examination marks

3 Conclusions and prospects

The search for the latest and effective technologies for the formation of professional competencies in higher maritime vocational education is conditioned by the requirements of normative documents, rapid informatization of navigation and requirements of employers.

It is the use of modern VR simulators helps to find new approaches in shaping the professional competencies of future ship navigators with the departure from traditional teaching, in favor of the requirements of time and achievements of science and technology.

The main objective of using simulation technologies is to provide the new quality of the professional training of future navigators by immersing the students in the real atmosphere of solving quasi-professional tasks, optimal for the formation of professional competencies and personal qualities of future ship navigators in conditions that are as close as possible to the conditions of future professional activity.

The following research on the use of VR simulators in order to develop the professional competencies of marine specialists will include the development of methodological support, which will be reflected in subsequent publications.

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