Mixed Reality Technologies as a Tool to Form Professional Competency of Sea Transport Professionals

Vasyl Cherniavskyi[1[0000-0001-7551-4186]], Halyna Popova[1;2[0000-0002-6402-6475]], Mykhailo Sherman[3[0000-0002-6560-4601]], Serhii Voloshynov[1[0000-0001-7436-514X]], and Alona Yurzhenko[1;4[0000-0001-5120-620X]]

[1]Kherson State Maritime Academy, 20, Ushakov ave., Kherson, 73000, Ukraine
[2]spagalina@gmail.com
[3]Kherson State University, Kherson 73000, Ukraine
[3]sherman_m@ukr.net
[4]helen18@online.ua

Abstract. The article is devoted to the use of mixed reality facilities in the training of future sea transport professionals. It says that one of the means of improving training technologies in maritime education is the use of simulators. The work lists the definitions of "mixed reality" term, which most of the scientists de ne as the merging of real and virtual worlds to produce new environments and visualizations. The article also describes the use of virtual-real training vessel in Kherson State Maritime Academy, which includes 19 laboratories, 16 simulators and 21 classrooms. The list of the main laboratories and their functions is given. The advantages of virtual-real training vessel built by means of mixed reality are described. The part of simulator exercise list is given. The article describes the results of experimental study of future navigators' professional navigational competence development with mixed reality simulation technologies. The authors made the conclusion that the use of mixed reality facilities allows to optimize the process of professional training and contributes to the effective formation of professional navigation competence of maritime specialists.

Keywords: Mixed reality, Maritime professionals, Virtual-real training vessel, Professional competency.

1 Introduction

The implementation of modern digital technologies into the daily practice of maritime navigation, the continuous and steady increase of the level of automation on ships create a further problem related to the "human factor" phenomenon. It is the use of high-tech intelligent systems that provide navigation safety, leading to the fact that sea transport professionals are increasingly questioning the decision in the field of maritime safety intelligent technical means, which significantly reduces their own production activity, allow the navigating staff not to use their active forces knowledge and practical experience [1].

International Maritime Organization (IMO) has adopted a comprehensive long-term of e-Navigation concept. According to the accepted definition, e-navigation is defined as "the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment"[2].

2 E-navigation

The concept of e-Navigation means improving and expanding traditional navigation by integrating human and machine capabilities. Currently, many ship and shore navigation with communication systems are used to ensure sea and river transportation (Fig. 1).

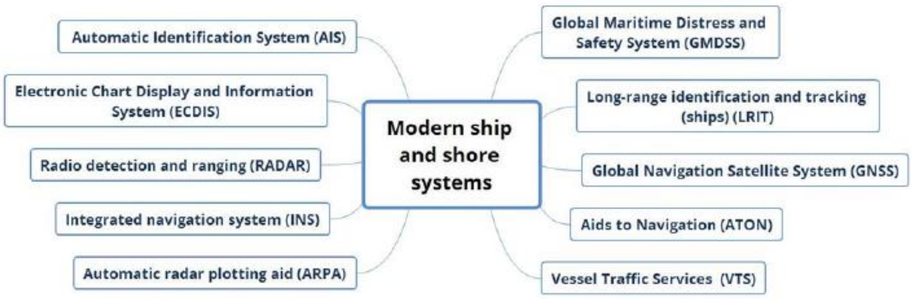

Fig. 1. Modern ship and coastal systems.

One of the tasks of e-Navigation is to revise the existing approach to ensure that seafarers are involved in the navigation process not only controlling it. This will allow seafarers to increase their decision level and use reliable electronic technologies and information management systems that reduce the number of distractions.

The consequence of such significant changes in the navigation process is the rapid increase in requirements to future ship navigators in the international labor market, who must be ready to work with digital generation tools, able to navigate complex professional environments, learn over a lifetime, improving professional competencies with the trend of continuous updating of digital trends equipment.

All this has led to changes in the organization of the educational process in the institutions of higher maritime education, where the priority is to reorient its purpose – the formation of professional competences in the conditions of digital transformation, as well as updating the content of the educational process. One of the promising areas is the use of e-learning, which is based on the application virtual environments into the educational process, augmented and mixed realities, computer simulations, virtual 3D worlds with immersion effect. The need to engage students in virtual forms of interaction is a consequence of the redevelopment of the educational space, which has been proclaimed as a mod-ern educational trend in Horizon reports [3-5]. And if 2016 saw major global trends in higher education included "augmented reality" (AR) and "virtual reality" (VR) technologies, which are defined as mid-term visualization technologies, then in the 2018 report all these technologies are already combined with the term "mixed reality" (MR), for which four to five years have been allocated to the educational process. Imaging technologies (3-D printers, information visualization, AR and VR, visual data analysis, 3D and holographic playback) combine the brain's ability to quickly process visual information, identify similar moments, and intuitively handle difficult situations.

3 Simulators use

3.1 Marine simulators

The use of real ship management systems in training is costly and carries both a risk to the lives of cadets and a risk of technical equipment damage. Therefore, one of the means of improving training technologies in maritime education is the use of simulators.

The professional competence of future ship navigators should be ensured in accordance with the requirements of the International Maritime Organization (IMO), which defined the training and introduced it in the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (2010 Manila Amendments) [6].

The rule 1/12 "Use of simulators" specifies that the performance requirements and other statements set out in section AI/12, as well as the other requirements set out in Part A of the STCW Code for any relevant diplomas/documents, must be complied with in respect of:

1) all compulsory training based on the use of simulators;

2) any competency assessment required by Part A of the STCW Code and carried out by means of a simulator;

3) any demonstration by means of the training equipment of professionalism required by Part A of the STCW Code.

The amendments made by the IMO to the Convention in 1995 defined the operational requirements for a number of simulators and introduced training and assessment of competencies using simulators for the first time in international regulatory practice. The 2010 amendments clearly set out the single requirements for the mandatory use in the educational process of simulators such as ARPA (automatic radar plotting aid), the use of radar and the simulator to work with the Electronic Chart Display and Information System (ECDIS). At the same time, the Code in the tables of competencies directly indicates the use of these simulators as a tool for learning practical skills in training a seafarer, and as an assessment of the acquired skills in training. Emphasis is placed on the compulsory physical and behavioral realities of simulators.

Ensuring the highest level of efficiency in the formation of professional competencies occurs in terms of practical onboard training, which is high-value and complex in terms of organization. Practice cannot ensure the development of skills and decision-making in a variety of emergency situations because they may not occur. That is why training is the main means of shaping the professional competencies of future ship navigators due to the high level of approximation of the training process to the real actions on the ship [7]. And the use of simulation technologies has allowed to bring the practical skills of navigation to a new level without threatening the life and health of people.

Modern generation simulators using virtual, augmented and mixed reality allow us to bring the training conditions closer to the realities of navigators when operating a ship, navigation simulators largely ensure the fulfillment of psychological-didactic requirements for the process of knowledge and skills formation.

In the context of our study, we have analyzed the current vision of the role and place of MR simulation technologies in professional scientific discourse from the standpoint of taking into account the specifics of the professional activity subject field of future maritime specialists.

Simulators are widely used in the training of maritime students worldwide. Ukraine has no deep experience in the use of MR simulation technologies precisely in the higher maritime education system. Therefore, the approval in 2018 of a new maritime higher education standard for the first (bachelor) level aimed at building competencies of the 21st century [8] has determined the landmarks of changing the educational paradigm for optimization of training, integration of simulation technologies into the educational process. It I needed to effectively shape the professional competencies of future ship's commanding officers.

3.2 Modern scientists' research

Among the works devoted to training and practical training of cadets in maritime educational institutions the works of S.D. Aizinov, V.M. Andrieiev, O.P. Bez-lutska, L.D. Herhanov, V. Dulin [9], D.H. Korneiev [10], Ye.V. Pasynkov [11], V.P. Petelin should be highlighted. The research of S.D. Aizinov, V.M. Andrieiev and V.P. Petelin was related to the technical capabilities of the simulators and are dated 1993-2007. V.M. Dulin investigated the use of training centers. L.D. Herhanov and D.H. Korneiev investigated the use of simulators in the process of professional competencies' formation of future maritime professionals. O.P. Bezlutska investigated psychological aspects of simulation training. Among foreign researchers A.A. Latin , D. Bouras, Dennis G. Tan [12], Hesham M. Helal, O. Lindmark, Trong Hieu Pham [13], C. Sellbeg, Y. Sendi [14] and W. Zhang [15] should be distinguished.

The scientists have noted that the impact of modern technology on the equipment of modern ships has increased the need for advanced training tools such as simulators, and the world has recognized the value of simulation systems as a learning tool. Simulation training is one of the main techniques for the practical training of maritime professionals in developed countries. In addition, the factors that contribute to the development of simulation training include a competency-based approach to learning and changing the paradigm of education with a focus on dual and continuous training, the implementation of blended learning.

Y. Sendi notes that the term Maritime Simulation Training (MST) – simulation training in maritime education – is not just a revolution in the world of educational technology, but a key strategy for improving all aspects that cover and regulate safety at sea. Moreover, computer-based simulations are defined as a powerful learning tool that has the promise of revolutionizing the way we study marine sciences in the 21st century.

3.3 Mixed reality

Marine simulators with MR technology emerged at the beginning of the 21st century and ushered in a new era in professional maritime education where training systems used decades ago no longer meet the requirements of the modern simulator and simulator industry. They allow future ship navigators to work out the necessary skills with the obligatory observance of the algorithm of their fulfillment, bringing the technique of their execution to automatism.

With the advent of the latest generation of digital simulators that incorporate MR technology to simulate the process of managing a complex technical system, the idea of using computer and telecommunications technology in education has completely changed. It is MR simulators that are of interest to us in our research.

MR simulation technologies is one of the methods of interactive learning that achieves its goal by immersing learners in the atmosphere of solving quasi-professional tasks. Based on MR simulation technologies, professional competencies are being formulated and evaluated in maritime educational establishments. The simulators can be the best source for demonstrating the professional competencies of a maritime specialist, both individually and as part of a shipboard team, by immersing themselves in the real work environment of a ship in the open seas, resulting in the improvement of certain maritime skills in navigating tasks over a very short period of time [16].

3.4 Types of realities

With the continued development of technology in education, immersive or extended reality (XR) technologies are becoming increasingly available. Extended reality is a common term for many kinds of realities. Augmented, virtual and mixed reality are the most popular types of XR.

Virtual Reality (VR) and Augmented Reality (AR) are two closely related technologies that have some differences and are a new trend in digital technology. VR creates real-world similarities through technical means. The created effects with the help of projection penetrate into the human brain and cause feelings as close to real as possible. VR is defined as a new concept of using computers and a human-machine interface to create the effect of a three-dimensional environment in which the user interacts with virtual objects, while creating a strong sense of three-dimensional presence. VR allows users to immerse themselves in the computer-generated world and experience the sensory experience there [5].

Virtual reality is characterized by the following factors:

1) presence (the illusion of being in another place, world);

2) immersion (sensory organs process information obtained from objects and events of the virtual environment);

3) involvement (all thought processes are focused on virtual interaction). Augmented Reality (AR) is an image superimposed on real-world objects.

AR is characterized by the inclusion of digital information (images, video and audio) in the real space, attempts to connect the real world with the virtual environment, allowing users to interact with both physical and digital objects [5]. The Association of User Technologies (CTA-2069 standard) also highlights Mixed Reality (MR), which is a seamless blend of real-world and digital content where both environments exist to create experiences [17].

All types of realities have differences in the characteristics they belong to: the reality of the virtual objects being displayed, the level of immersion in the virtual space and the way all components interact. In 1994 P. Milgram and F. Kishino first described the mixed-reality model (the continuum of reality-virtuality). They explained their concept as an interaction between the real environment and the virtual environment at different levels (fig.2).

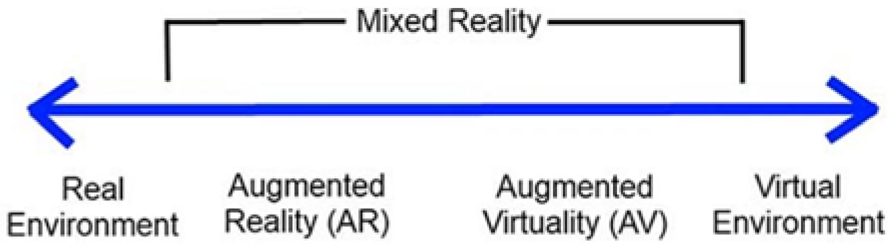

Fig. 2. The model of Mixed Reality.

3.5 Definition of MR in the scientific discourse the list of researchers and their definitions

The subject of our study required a more detailed consideration of the question of the "mixed reality" term interpretation. To this end, the definitions of "mixed reality" that scientists and researchers, developers of the latest technologies have been studied and analyzed. The results of this work are presented in the list of researches and their definitions (Table 1).

Table 1. Analysis of the interpretation of the "mixed reality" concept.

Researchers	The definition
I. Morozov	Mixed reality combines elements of both AR and VR, interacting with real and digital objects, the real and virtual worlds combined, and cannot be clearly delimited.
Observatory of Educational Innovation [18]	MR is a combination of AR and VR: augmented reality subcategory that inserts 3D images into the real world.
Hubr [19]	MR is defined as blended reality: this technology incorporates elements of augmented reality in addi-

	tion to physical presence.
IT enterprise [20]	MR is interpreted through the general concept of computer-mediated reality or mediated reality.
Iguides [21]	MR is an interactive type of virtual reality that has the highest level of capture where virtual objects interact with the real world.
Mixed Reality in the Maritime Sector Project [22]	MR is the result of combining the physical world with the digital world. MR is the next evolution of human, computer and interaction environments, creating unlimited possibilities.
P. Milgram and A.F. Kishino [23]	The merging of real and virtual worlds to produce new environments and visualizations, where physical and digital objects co-exist and interact in real time. MR does not exclusively take place in either the physical or virtual world, but is a hybrid of reality and virtual reality, encompassing both augmented reality and augmented virtuality via immersive technology

As can be seen from the table, the terminology base is in the process of being formed, but all researchers explain MR as a combination of virtual objects and a real environment. Moreover, as stated at the 2018 Google I/O Annual Conference: "VR /MR/R/RR are not separate and well-defined things, but convenient labels for different points in the spectrum" (RR – real reality).

Modern marine simulators contain replicas of real-world equipment and digital virtual reality augmentation, which in turn helps to increase the realism of training to the highest level and provide new opportunities to shape and evaluate the professional competencies of future maritime professionals. The emergence of new technologies and opportunities in maritime education is the tendency to move from eLearning to simulation – SBL (Simulation Based Learning), which includes simulation training, online learning. With regard to virtual reality technologies used in offshore simulators, researchers believe that the main positive driver of virtual technology training is immersion in a virtual professional environment. It is a kind of computer "game" that allows you to move from simple models to assessing the impact of professional environment to manage and minimize these impacts, mitigate the effects of economic losses. Foreign researchers share this view. They note that VR is a valuable teaching method that provides real-world experience for students through role-playing games and modeling technology. In VR, there is a phenomenon of kinetosis – the indicators of the vestibular apparatus and sensory organs differ because the person sees the movement but the body remains at rest. The brain perceives visual information as a hallucination that can be felt during poisoning, and nausea arises. Similar feelings also exist when creating the effect of being in the sea. The effect of sea-sickness is very similar to real feelings, getting used to it can even help future navigators in the future.

Often there are discussions in the literature about the use of modern digital technologies in the educational process.

This is due to the fact that today these technologies are only developing and there is a small amount of knowledge, which always creates anxiety and concern. A number of researchers point out the following reasons:

1) incorrect assessment and lack of understanding of the using modern digital technologies in education possibilities;

2) a misconception about the ergonomic characteristics of modern hardware;

3) the lack of methodologies and well-designed programs are a cause for concern for the use of such tools by the pedagogical community or for their poor implementation in the educational process [24].

In traditional training, cadets acquire knowledge from individual disciplines, and the combination of acquired knowledge occurs in practice only after a few years. Using MR simulators allows you to gain experience in each role according to specific scenarios in the learning process itself. In the simulation lesson, the priority is precisely the educational task, in the process of which a negative result is assumed in order to be able to feel a degree of responsibility [25]. It should be noted that an important aspect of the successful formation of professional navigation competency of future navigators by MR simulation technologies is the development of a methodological environment. It includes training manuals, guidelines, instructions for practical tasks, etc., and most importantly, the recommendations and instructions for the development, filling and use of simulation technologies MR in the process of professional training of maritime specialists[14].

All this has created the necessary prerequisites for conducting our study on the use of the latest information technology (simulation) in the educational process in the formation of maritime specialists' professional competencies.

4 KSMA experience in the simulators use

"Virtual-real vessel" as an informational pedagogical infrastructure is used in Kherson State Maritime Academy.

The modern KSMA facilities in terms of volume and content corresponds to all components of a virtual-real training vessel. Transas Ukraine Ltd. Shipping & Marine Supplier developed the software of KSMA electronic simulators with the following components: NTPro Configuration Editor, Router, Navi Trainer Instructor, etc. This company is a leader in the market of maritime training systems in Ukraine, carrying out the supply and support of a wide range of training systems because of the good quality of software. The educational and training complex "Virtual-real vessel" created by it includes 19 lab-oratories, 16 simulators and 21 classrooms, the examples are:

- Navigation Bridge Integrated Simulator, including Electronic Charts and Navigation Systems Class, Radar/ARPA Simulator Laboratory and Full-Mission Navigation Bridge (conducting of laboratory and practical classes on educational disciplines assigned to the department according to the curricula, improvement of the quality of educational process and active participation of staff in extracurricular work with future maritime professionals);

- Engine Room Integrated Simulator, which consists of two engineer rooms, Instructor's Workplace and Theoretical Training Classroom. The last one provides familiarization with the use of control and measuring devices and controlling means which are used in engine rooms onboard modern merchant vessels. It also gives awareness of necessity of proper preliminary planning, use of technical record-keeping sheets and schedules regarding the starting procedure. Cadets will gain experience in identification of operational problems and troubleshooting;

- Dynamic Positioning Integrated Simulator, which consists of Full Mission Navigation Bridge of Dynamic Vessel Positioning, Theoretical Training Class-room and Classroom with Separate Dynamic Positioning Stations (enhancement of the study process of Survey course of simulator training for state attestation);

- Global Maritime Distress and Safety System Simulator, which consists of two separate classrooms for practical training (improving the quality of educational process and active participation of the training laboratory staff in extracurricular work with cadets and students);

- Survival and Fire Fighting Centre (acquiring standards of competencies related to personal safety with regard to personal survival in compliance with the national requirements);

- Fire Fighting Ground (knowledge of coherent, prompt and consequent actions in firefighting onboard ships in the maximally close to reality conditions as well as confidence and readiness to act in extreme circumstances related to life threatening);

- Mooring Station (knowledge, understanding and acquiring of professional skills by cadets related to taking decision as to mooring which should be based on proper evaluation of maneuvering characteristics of a ship and its power plant as well as forces which are expected to take actions during berthing, ensure fulfilment of safety-first requirements when performing operations);

At the heart of the project is the task to use in full the created complex of training, practical and educational facilities; to develop the necessary methodological software and to involve in its implementation appropriately trained scientific personnel, professional maritime specialists of high qualification and representatives of maritime industry management. Involvement of experienced professional seafarers into participation in the project will allow us to simulate close to real life extreme conditions of cadets' watchkeeping at existing KSMA facilities, structured in a virtual reality vessel structured in KSMA. This allows cadets to master the professional knowledge and communication skills and to further demonstrate them while working on the ships of the international crews during the theoretical classes and practical watchkeeping at virtual-real training facilitates of the educational institution.

MR technology training enables each student to actively participate in the educational process, to demonstrate their knowledge and acquired competences through the organization of a learning process in small groups, which allows to implement an individual approach to each cadet. Continual working relationships are formed between the teacher and the student, which results in a significant increase in the assimilation of both theoretical and practical knowledge [26].

The lesson consists of the following steps:

- briefing, which assesses the situation, equipment, identifies the object and purpose;

- the process of simulation training, in which an important condition is a maximum sense of the reality of the situation (fig.3, 4);

- summing up, analysis (debriefing): at this stage it is important to understand that simulation reflects real life, and there are no personal mistakes, there are only team errors.

Fig. 3. Navigation Bridge Integrated Simulator use by cadets.

Fig. 4. ‘Heavy Cargo Loading Operations” simulator (supplier ARI, India) use by cadets.

The process of learning and developing practical skills is recorded on camcorders, which allows for debriefing to carry out a careful analysis of situations, actions, students' behavior, to identify mistakes. Thus, the student carries out self-assessment of theoretical training for professional activity, stimulates himself to additional independent education, knowledge completion. Formation of professional competences is controlled by means of expert evaluation letters (check-letters). This assessment allows the teacher to more objectively analyze the completed task and identify errors. The teacher evaluates the quality of readiness for professional activity, the formation of professional competences and, if necessary, makes adjustments to the theoretical training course in order to improve the basic training. The results of the simulations show that this form is of great interest and motivation (Table 2).

Table 2. Part of simulator exercise checklist.

Cadet must:	Maximum points amount:	Task 1: maneuvering data. Deep water. Navigating zone - Open Sea. Type of ship - Bulk Carrier6. Approach speed V = 0 *knots*. Initial course - 0 *degrees*. Wind direction 0 *degrees*, Wind speed 0 m=*sec*.		
		Done	Undone	Partially done
1. Snap telegraph from "Stop" position to "Full ahead for sea" position.	3			
2. Correct the vessel course and every minute read speed V(t) and distance covered S(t).	6			

5 Experimental check of the results

In order to check the results of mixed reality use the pedagogical experiment was held in KSMA. The experiment's primary focus is on the specific implementation of the educational process with the aim of forming professional navigational competence of future navigators with MR simulation technologies in the process of studying professional disciplines.

The number of participants in the experimental verification of the control and experimental groups was 226 cadets, which provides the probability of statistically significant indicators of the effectiveness of future navigators' professional navigational competency formation with the help of MR simulation technologies. The study included 112 control group cadets and 114 experimental group cadets.

Assessment of levels of professional navigational competence by cognitive component was made by exam results and results of interviews with Marlow Navigation crewing company, questionnaires about level of digital competency's formation of cadets [27, 28].

The dynamics of changes in the levels of professional navigational competency's formation of future navigators by cognitive component showed that the results of the experimental group far exceed the results control group (Table 3).

Thus, the number of cadets with a high level in controlled group increased from 8.04% to 9.82%, and with an average level – decreased from 67.85% to 58.93%.

In contrast to the control group in the experimental group there was a positive dynamics of indicators of professional navigational competency formation: the number of cadets with a high level increased from 6.14% to 18.42%, with an average level decreased to 42.98% from 70.18%.

Table 3. Evaluation of the levels of the navigational professional competency for cognitive component before and after the forming stage of the experiment.

Levels	Before experiment				After experiment			
	Control group		Experimental group		Control group		Experimental group	
	Persons	%	Persons	%	Persons	%	Persons	%
High	9	8,04	7	6,14	11	9,82	21	18,42
Sufficient	27	24,11	27	23,68	35	31,25	44	38,6
Intermediate	76	67,85	80	70,18	66	58,93	49	42,98

The results of experimental group are much better than control group's ones. It can be seen in the graphical representation of fig.5.

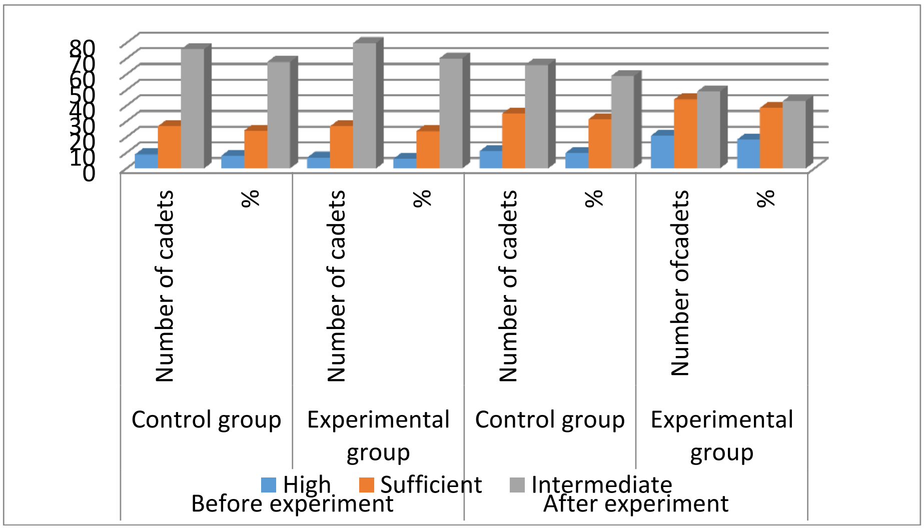

Fig. 5. Graphical representation of experiment's results.

Formation of cognitive component is ensured through the systematic immersion of cadets in professional situations and the development of professional skills through a system of active and interactive forms of training using the latest digital technologies, among which MR simulation technologies [29].

We conclude that the use of MR simulation as positive impact on future maritime specialist's professional and digital competencies. With the help of the method of mathematical statistics, this statement was proved.

6 Conclusions

A necessary step is to raise the quality standards of training of future sea transport professionals, who must be ready to work with a variety of information in digital form, be able to choose effective forms of ship management to ensure maritime safety, be responsible for management decisions.

The analysis of pedagogical research on the problem of professional training of future ship navigators showed that in modern conditions the requirements to the professionalism of the future navigator, his competence, development of professional qualities, ability to work in a team and ability to take responsibility significantly increase. Based on the analysis of basic scientific ideas, theories and approaches to the study of the problem, it is determined that the formation of professional navigation competence of future ship navigators in maritime education is a continuous process of gradual inclusion of cadets in educational and professional activities.

It has been found that mixed reality simulation technologies play an important role in the formation of professional navigation competence of future sea transport professionals, as they provide the maximum approximation of training conditions to the conditions of real reality of navigators in ship management. It is determined that MR simulation technologies are the integration of real professional equipment with VR simulators, which creates a highly realistic, immersive, interactive environment, resulting in the development of professional thinking and a significant increase in the formation of professional competencies.

Therefore, the formation of professional navigational competency of future navigators by means of MR simulation technologies is an important systemic indicator of the effectiveness of their training. The analysis of the results of the experimental work showed the validity of our hypothesis. The process of formation of professional navigational competencies of future navigators by means of MR simulation technologies is effective if it is carried out under introduction into the system of professional training of future sea transport professionals the facilities of the KSMA Virtual Reality Vessel.

References

1. Vagushchenko, L.: Modern information technology in navigation. ONMA, Odessa (2013)
2. International Maritime Organization, http://www.imo.org/. Last accessed 23 Jan 2020

3. NMC Horizon Report, https://library.educause.edu/resources/2018/8/2018-nmc-horizon-report. Last accessed 25 May 2019
4. BCI Horizon Scan Report 2019 https://www.thebci.org/resource/horizon-scan-report-2019.html. Last accessed 25 May 2019
5. Publication of Higher Education 2017. NMC.ORG. https://www.nmc.org/publication/nmc-horizon-report-2017-higher-education-edition-russian/. Last accessed 11 Mar 2019
6. International convention on standards of training, certification and watchkeeping for seafarers STCW. IMO, London (2011)
7. Aisinov, S.: Theoretical and methodological foundations of creating an expert system for assessing the effectiveness of marine simulators: the example of GMDSS simulators, (2007)
8. The Standard of Higher Education, https://mon.gov.ua/storage/app/media/vishc ha-osvita/zatverdzeni%20standarty/12/21/271-richkoviy-ta-morskiy-transport-bakalavr.pdf. Last accessed 28 Dec 2019
9. Dulin, V.: Development of professional experience of maritime specialists in training centers, (2006)
10. Korneev, D.: A situational-task approach in the formation of the competence of a ship navigator in a training simulation of reality, (2005)
11. Pasynkov, E.: Ship management information support system, (1999)
12. Tan, D., G.: The virtual classroom afloat – maritime education and training in the 21st century: an investigation into the feasibility and practicability of distance learning via the satellite communications system. World Maritime University Dissertations, (1999)
13. Pham, H.: Virtual MET Institution : assessing the potentials and challenges of applying multi-user virtual environment in maritime education and training. World Maritime University Dissertations, (2012).
14. Sendi, Y.: Integrated Maritime Simulation Complex Management, Quality And Training Effectiveness From The Perspective Of Modeling And Simulation In The State Of Florida, USA. Electronic Theses and Dissertations. https://stars.library.ucf.edu/etd/1399. Last accessed 11 Mar 2019
15. Zhang, W.: Assessing the competency of seafarers using simulators in bridge resource management (BRM) training. World Maritime University Dissertations, (2017)
16. Asghar, A.: Role and importance of the simulator instructor. World Maritime University Dissertations, (2006)
17. Technology Definitions and Characteristics of Augmented and Virtual Reality Technologies CTA-2069. https://scta.tech. Last accessed 23 May 2019
18. Edu Trends. Augmented Reality and Virtual Reality. Observatory of Educational Innovation https://observatory.tec.mx/edu-trends-augmented-and-virtual-reality/. Last accessed 27 Aug 2019
19. The use of VR, AR and MR in simulation and training, https://habr.com/ru/post/409337/. Last accessed 14 Dec 2019
20. Augmented, virtual and other realities, https://www.it.ua/ru/knowledge-base/technology-innovation/dopolnennaja-virtualnaja-i-prochie-realnosti. Last accessed 10 Jan 2020
21. Virtual Reality vs Augmented Reality vs Mixed Reality, https://www.mtvrse.ru/virtu alnaya-dopolnennaya-smeshannaya-realnosti-otlichiya. Last accessed 24 Jan 2020
22. Mixed Reality in the Maritime Sector Project Report Copenhagen. https://static1.squarespace.com/static/56a0c84dfb36b1be19213613/t/5bdc23f3aa4 a99dca82fe516/1541153780642. Last accessed 27 Aug 2019.
23. Milgram, P., Kishino, A.: Taxonomy of Mixed Reality Visual Displays. IEICE Transactions on Information and Systems. 1321-1329 (1994)

24. Kurzaeva, L., Maslennikova, O., Beloborodov, E., Kopylova, E.: To the question of application of virtual and augmented reality technology in education, https://www.science-education.ru/ru/article/view?id=27285. Last accessed 28 Dec 2019.
25. Simulation training in the specialty "General Medicine." GEOTAR-Media, Moscow (2014).
26. Blokhin, B., Gavriutina, I.: Simulation as an innovative method of teaching emergency pediatrics. Medical education and professional development. 3, 112-119 (2011).
27. Popova, H., Yurzhenko, A.: Competency framework as an instrument to assess professional competency of future seafarers. CONFERENCE 2019, ICTERI, vol. 1, pp. 409{413. Kherson, Ukraine (2019).
28. Voloshynov, S.: Implementation of blended learning in professional training of future marine specialists. 1 (70), 104-120 (2019).
29. Nosov, P., Zinchenko, S., Popovych, I., Safonov, M., Palamarchuk, I., Blakh, V.: Decision support during the vessel control at the time of negative manifestation of human factor CEUR Workshop Proceedings, 2608, 12-26 (2020).