Quality assessment of future navigators' training by means of VR-technologies

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Abstract

The article presents the specific features of using VR technology in the training of future marine specialists on the example of the discipline "Navigation information systems". The recent studies on the use of such systems have already proven the need for their integration into the educational process. The complexity of assessing of navigational circumstances that are constantly changing, the complexity of ECDIS interface do not allow navigator to respond promptly to changing circumstances. So during training, they must be prepared on models as close to reality as possible. A model for the use of VR system has been chosen in order to increase training efficiency for dynamic control systems. The requirements for software and hardware parts of the proposed model for consolidating practical navigation skills are formulated. The studies have shown that initially students had almost the same level of knowledge, and after using of VR technology to acquire the skills of correct actions in navigation situation assessing, the researched group increased the speed of actions, contributed to more successful exercise on a simulator. The t-criterion of Student was used to assess the value of statistical data analysis. Possible ways of developing such systems have been identified in the planning of education in specialized disciplines, the practical part of which consists of managing dynamic systems in a simulated reality and requiring maximum attention to the data set.

Keywords

VR – system, navigational information system, navigators, technical means of navigation, ECDIS.

1 Introduction

Information technologies have recently been developed not only in production processes, management, but also in higher education. A study by Yale University showed that the assimilation of educational material, for example, from surgical manipulations using VR simulators, was 29% faster, while students made 6 times fewer mistakes. In Beijing, 93% of students in the research group using such simulators successfully passed the final test, which exceeded by 20% the achievement of the control group without using of such technology [1]. Also, these areas focus on the better assimilation of the material of the research groups – after a two-week period from the day of final testing, compared to the traditional form of study. The training center "Desna" of the Armed Forces of Ukraine also uses this technology with the developed software Virtual Battlespace, in which the environment is close to combat [4]. In Poland, future surgeons work with the surgical VR-system Laparo [2]. Some researches [3] provide information on the use of this technology in plastic surgery.

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The article provided general overview of areas of higher education that are already being implemented at different stages in the training process of using virtual headsets [5,6]. Also, the opportunities of AR-technology implementation for improvement of education quality [7] are provided in this article and in TeslaSuit company developments [8,9]. However, there is whole branch of education where such technologies cannot be quickly deployed, as there is high degree of complexity in input data for assessing the situation and making decision in a time-limited environment: ship management, aircraft and other complex dynamic systems.

The trend of recent years is the digitization of navigational equipment and the complications of technical aids to navigation and systems, which are used during vessel traffic. But world statistics show that the human factor remains the main cause of maritime incidents [10]. The sad statistics are replenished by several reasons: fatigue of the watch personnel, investigated by Ukrainian scientists [11], uncertainty and incompetence of the command personnel, lack of necessary professional skills of key crew members (Captains and Officers in Charge of the Watch) – it has a negative impact on the safe operation of the ship and the lives of people.

It is therefore relevant to improve the quality training standards of future marine professionals, who should be trained to work with variety of information in digital form, be capable of choosing effective forms of ship management to ensure the safety of navigation and be responsible for the management decisions taken.

Requirements for the content of maritime education are determined by the regulations of the International Maritime Organization (IMO) [12]. The Manila amendments of 2010 specified the minimum requirements for the competence of seafarers at three levels: management, operation, subsidiary level, conditioned the implementation of the amendments provisions by strengthening the practical orientation of the educational process through exercising practical skills on simulators, regulated the use of modern electronic means and methods in training according to STCW [13].

In institutions of higher education in the specialty "Navigation" in most professional-oriented disciplines, simulators are used to master the skills of working with a large number of navigation equipment, which is characterized by complexity and diversity of interfaces depending on the models of devices and their manufacturers.

At the same time, the understanding of the basic operating principles of such devices and the acquisition of modelling skills offer real advantages in terms of watch keeping compared to only theoretical knowledge. The acquisition of practical skills by applicants is an integral part of the training for such a profession. However, there are usually a number of difficulties in the implementation of vocational training in the educational process: requirements of employers (international crewing companies) clearly define that the formation of professional competences and their evaluation should take place by means of modern simulators, electronic training of modern visualization system. In practice, the theoretical and practical bases for their introduction into the educational process during the teaching of professional subjects are insufficiently developed. But the clear requirements for efficiency and the magnitude of potential losses, both on the part of the ship owner [14] and, in some cases, of the environment, require a transformation of professional disciplines teaching approaches in the training of future seafarers.

There are already VR technologies that are used to train seafarers in safety [15] and work with various mechanisms [16], and an example of ECDIS simulator is given [17], the last one still requires the physical presence of simulator to work out the exercises.

The analysis of scientific publications on the use of VR technologies in education shows a high rate of development and further potential for application.

In addition, the problem of the development of virtual reality simulation technologies in combination with e-learning in the professional training of the future navigator, as well as the corresponding experience on the example of Ukrainian marine higher educational institutions, were not sufficiently represented in the research of scientists and require additional consideration.

The aim of the study is to select a model for increasing the efficiency of training material in a practical context using virtual technology (VR) for the ability to ensure safe navigation.

The result of the research is the construction of a conceptual model of professional training of navigators, which is aimed at the formation of professional competencies by means of digital, simulation, cloud and distant technologies.

2. The theoretical basis of research

World Maritime University (WMU), founded by IMO, provides each year relevant reports on the improvement of the quality of education for navigation officers [18]. The report 2021 (fig.1) provides an analysis of the structural elements of such training: by traditional means in classrooms, with the help of e-learning by simulator training. A survey conducted after training showed that students demand more use of e-learning elements, Internet technologies. This is primarily due to the additional time for the perception of information in conditions that give more comfort outside of educational institutions. There is possibility of revising exercises and theoretical material.

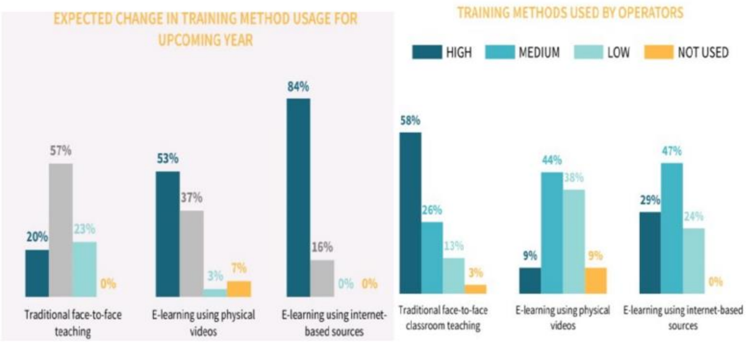

Figure 1. Expectations and practical methods of training by specialized training centers and advanced training of navigators [18]

In addition, most educational institutions in this area still use traditional methods with specific weight of 0.58, while those surveyed require a reduction to 0.2 and an increase in the proportion of e-learning to 0.53–0.84. These studies show that there is a need to restructure the training components in an electronic direction with better information.

Almost 95 per cent of the training centers for navigators' plan to increase the effectiveness of crew training in the future through the use of tools: simulators; computer-based training systems; development of scenarios and copying of ship equipment to create realistic events; virtual reality. Chinese marine education researchers have identified the benefits of learning using VR technologies, among which the possibility of operating virtual reality equipment according to established rules, establishing different conditions of equipment malfunction, understanding the process of composing the internal structure of the device; planning the own training time, checking the learning effect using the system evaluation function; possibility of repeating the training, regardless of time and space constraints [19–21].

Along with them, marine education institutions should also increase the effectiveness of education, including the latest digital technologies. If elements of such technologies are identified among all means of learning, the "ideal" training initiatives may include: introduction of simulation technologies of augmented, virtual and mixed reality; introduction of modules on the evaluation of training on a simulator; introduction of blended learning.

At the same time, there is a need to introduce innovative teaching methods, such as: transferring traditional teaching material to e-learning and increasing its share, using Gamification, adaptive learning technologies, depth learning and digital learning technologies.

Some professional disciplines may additionally use virtual (VR) and augmented (AR) reality technologies to increase material assimilation efficiency. Such technologies have some advantages over traditional teaching methods:

1. Safety. Applicable to the study of complex management processes without risk for students and the court.

2. Visibility. The ability to visualize processes and objects. Ability to design any interaction of objects.

3. Unlike AR-technology, VR-technology has the user's attention due to the full immersion in the virtual world.

In recent decades, information technology has been actively implemented in navigation, in particular Electronic Chart Display and Information System (ECDIS), which integrates various navigational devices, provide information in real time with the possibility of superimposition on an electronic card (for example, radar coverage). The purpose of such systems is to improve the safety of navigation, including combining of all possible information for navigator to make a decision. Navigation is significantly different from other technical specialties due to the use of the entire amount of acquired knowledge at once for the analysis of data from technical means of navigation, navigation and meteorological data, GPS, Echosounder, AIS, VHF control and radar data, ARPA. The diagram (fig.2) shows the devices integrated into ECDIS, which make it difficult to analyze dynamic information.

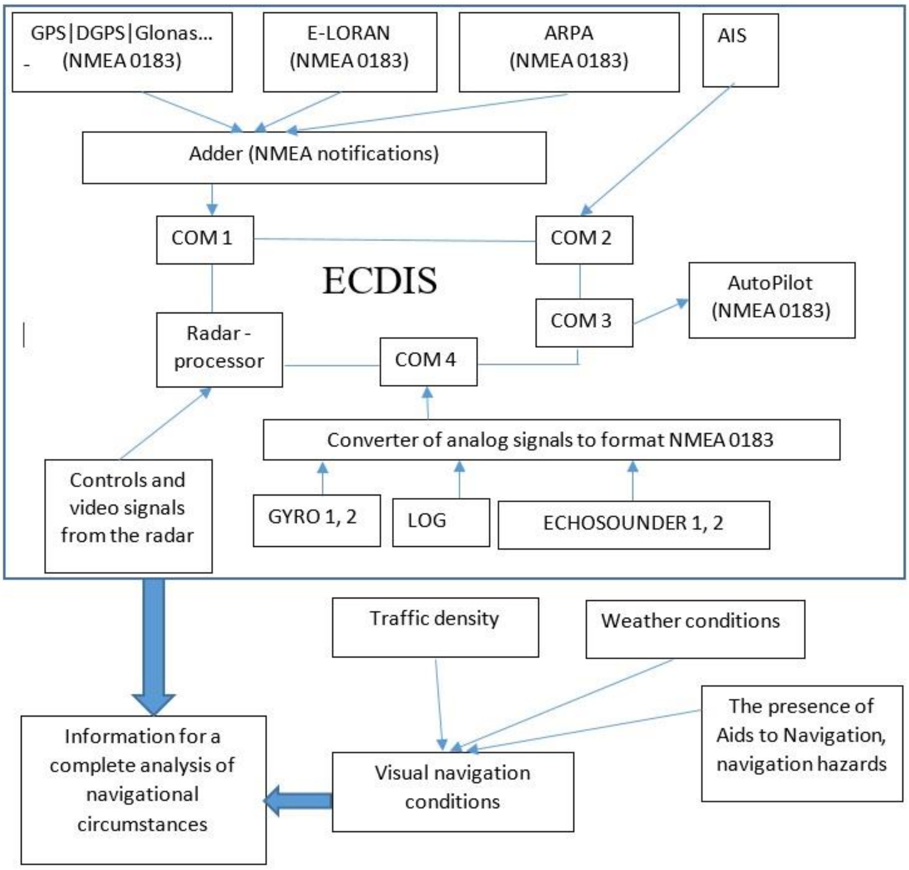

Figure 2. Structure diagram of sources of information to officer of the watch

The Academy has implemented a model for training of future maritime specialists.

Model elements:

• Blended learning, which is implemented with LMS MOODLE (provides 1,2,3 level of Bloom's taxonomy) and traditional classroom or laboratory teaching (provides 3,4 level of Bloom's taxonomy).

• VR simulator, which provides formation of competence for execution of task according to the created algorithm. Benefits – it is safe, possibility of an infinite number of attempts, ability to step back and automatically check.

• Real simulator on which the real training takes place (provides 3.4.5 level of Bloom’s taxonomy).

• Practical training on board. Each cadet has practice program and Record training book in which every type of work performed on the ship is recorded. This Book is certified by instructor’s signature and Captain’s seal. According to the regulations for each month, training sessions are held on the ship, the results of which are recorded in special logbooks (provides 3,4,5 level of Bloom's taxonomy).

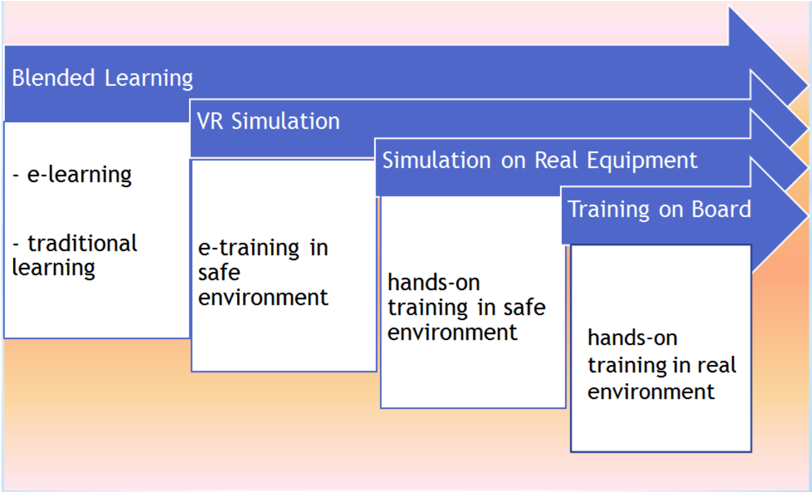

Figure 3. Model of Seafarers' Training

The blended learning system, taken for research, consists of e-learning: theoretical course of lecture material (for each lecture, appropriate testing of cadets is carried out), methodological material, presentations and videos posted on page of discipline "Navigation and information systems" is carried out; classroom simulator course to acquire practical skills in using ECDIS. As shown in previous years' estimates, this is not enough, since it is difficult for student to take large amount of information together in order to make the right decision when the time for making it is limited, due to the rapid change of navigational circumstances and the great inertia of the ship. It is proposed, after blended learning, to use VR technology for preliminary knowledge of dangerous sections of the crossing route, which may be approaches to port terminals, canals, and other narrows. At the same time, cadet, being at home, and having a VR-helmet / glasses, enters cloud resource, which broadcasts to the VR-helmet of screen user: visualization of the simulator – Coning Display | overview, ECDIS, radar and other elements of the navigation bridge. During the passage along the route, instructor comments are provided and attention is drawn to the indicators of the radar in overlay mode and other navigation devices integrated into ECDIS. That is, cadet may pass any difficult part of the route once more (fig.3), he has the opportunity to "go through" as many times as he needs to find out all the subtleties of ship steering under such weather and navigational conditions. In this way, the trainee receives additional information on changes in the parameters of control of the vessel in the event of changes in the external conditions of navigation. Thus, the student receives additional information on changing the parameters of the ship's control when the external navigation conditions change. Also, IMO Model Course 1.27 recommends that additional exercises should be carried out using pre-defective navigation device, such as deviation of its readings, and failure of device during passage [22].

Figure 4. Navigation bridge at the training center

The chosen model in training is VR technology using cloud services (fig.4), where the simulation of the exercise is viewed by cloud server. The simulated situation is displayed to the student – user of PC with Web Browser and Headset. The data about student's actions is transferred to Controller and Web Browser, further to cloud server – to further change the situation.

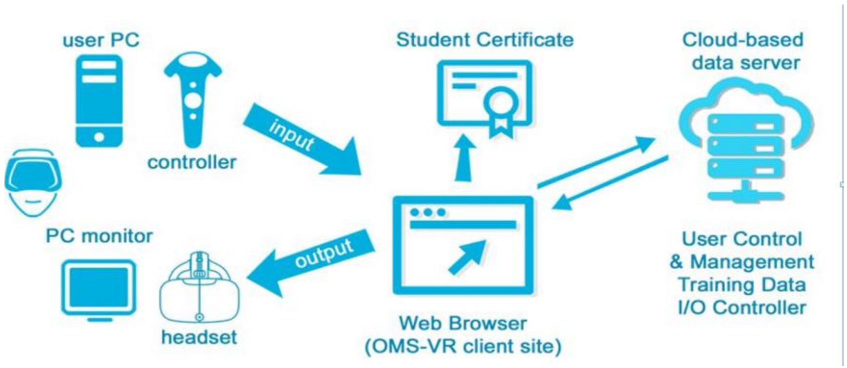

Figure 5. Conceptual diagram of integration of ECDIS simulator with VR technologies and cloud services

In guidance documents Det Norske Veritas (DNV) – Standard for Certification No 2.14. (October, 2007) it is defined that marine simulator is the creation of a certain state through modeling, simulation of situations in marine operation with physical and behavioral realism. As a consequence of the emergence of new technologies and opportunities in maritime education, there is a tendency to move from traditional training to simulation - SBL (Simulation Based Learning), which includes simulation trainings, interactive training.

The hardware requirements for using of such training scheme is that student should have: PC, VR glasses with appropriate controller, mid-level graphics card. Software requirements: high-speed Internet, Browser, supports VR and controller operation.

Additional advantages of the proposed use of VR-technology are:

• Building of the environment, which is perceived by the navigator's senses.

• The student independently perceives and rethinks all the information.

• It can be implemented using AR content on smartphones, tablets and interactive whiteboards.

After graduating from an educational institution, the cadet takes exams at a specialized inspection and receives Certificate of Competency, which gives the right to work on a ship, and every 5 years he undergoes refresher courses at training centers.

The system of evaluation of acquired professional competencies by discipline is presented in the table (tbl.1).

Table 1

Components and tools for assessing of training outcomes

Traditional teaching methods (face to face and LMS Moodle)	Cloud technologies	Means of assessment
Incoming knowledge control		testing
Outline using presentations		testing
Course of interactive lectures		testing
Training materials on description Navi Sailor 4000		Performing practical tasks on a simulator
Methodical instructions for laboratory work	video accompaniment	

Methodical instructions for individual work		
Proposed	**VR – video accompaniment**	**Performing practical tasks on a simulator**
Questions to prepare for final check		Final check (exam/credit)
Control of residual knowledge next year		testing

Methods of statistical analysis were used to determine the authenticity of the proposed model. There were selected equal (group 1) and non-equal (group 2) samples that are not linked:

$$t = \frac{|\bar{X} - \bar{Y}|}{S_d} \qquad (1)$$

X¯, Y¯ – midpoint value for subgroups A and B according to the chosen comparison criterion – accuracy (in terms of scores). S_d – mean deviation: (2) for equal and (3) for non-equal samples.

$$S_d = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2 + \sum_{i=1}^{n}(y_i - \bar{y})^2}{(n-1) * n}} \qquad (2)$$

$$S_d = \sqrt{\frac{\sum_{i=1}^{n_1}(x_i - \bar{x})^2 + \sum_{i=1}^{n_2}(y_i - \bar{y})^2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)} \qquad (3)$$

3. Experimental study

The discipline "Navigation Information Systems" forms the most important professional competencies of the navigator, such as: use of technical means of navigation and ECDIS to ensure the safety of navigation, including the functions of integrated navigation systems, route observation and information reflection; ability to conduct actions upon receipt of distress at sea; coordination in search and rescue operations; navigating in all conditions using appropriate methods to obtain an accurate positioning and make optimal use of all available navigation data for navigation.

KSMA training center has two simulators – full navigation bridges (for transport ships and for ships equipped with dynamic positioning system), where various models of ships (over 10) can be loaded in different navigation areas (over 15). Both bridges can be used by different types of vessels in any navigation area.

In the study there were used analysis of stakeholders, cadets' shipboard training reports, regulatory documents on professional maritime education, competence-based approach and assessment of competencies, analysis of scientific and methodological literature, dissertation research, curricula, textbooks and teaching aids, regulatory documents on the problem of organizing the educational process in institutions of higher maritime education, scientific literature and technical documentation.

At the beginning of the academic year, a cross-section of knowledge was conducted in the research groups to determine the level of competence for the possibility of using ECDIS. The knowledge from the following core disciplines was selected for testing (tbl. 2).

Table 2

Competence of previously studied disciplines required for the course "Navigational Information Systems"

Subjects providing initial knowledge for the study of the discipline «Navigational Information Systems»	Competences
Physics	research of real processes and optimal decision-making. Knowledge of the features of sound waves propagation in environments with different densities, influence of currents and wind on the vessel movement, determination of the point of vessel rotation.
Higher Mathematics	basic worldview knowledge, the ability to abstract, systemic and critical thinking, analysis and synthesis. Knowledge of the basics of trigonometry and mathematical modeling.
Computer Science	ability to use general-purpose software.
Global Maritime Distress Safety System	knowledge of message systems, radio communications during search, rescue and in case of accidents.
Information Technology	ability to search, process and analyze information from various sources; skills in software using. Knowledge of computer networks principles and use of Internet resources.
Marine Geography	determination of routes using Sailing Directions. Knowledge of the geographical position of the ports, their features.
Meteorology and Oceanography	ability to analyze weather forecast and oceanographic conditions to select safe route of the vessel. Knowledge of tidal phenomena, climatic features of water areas, the basics of the formation of meteorological circumstances, main methods of preventing their significant impact on the vessel
Navigation and Sailing Directions	ability to use conceptual knowledge and critically understand the basic laws, theories, principles, methods and concepts of navigation, to plan a voyage. Knowledge of use of paper navigational charts, appropriate techniques for obtaining the exact position of the vessel and making optimal use of all available navigational data for navigation.
Ship Handling	ability to use conceptual knowledge and critically understand the basic laws and practices of ships handling. Knowledge and understanding of the effect of tonnage, draft, trim, speed and depth under keel on the vessel maneuverability; effects of wind and current on ship handling; subsidence effect, shallow water effect.
Astronomy	ability to use the positions of the celestial bodies.
Electro Radio Navigation Equipment	applying appropriate techniques to obtain an accurate position and make optimal use of all available navigation data for navigation. Knowledge of radars and automated radar plotting tools to ensure safe navigation.

Each research group of cadets was divided into two subgroups, due to the limited number of places on the simulator – bridges (8 units). That is, when conducting a lesson on simulators, the number of cadets is limited – up to 16 people – 2 students per 1 navigation bridge. For blended learning: subgroup A – according to the usual method of self-preparation for practical exercises (control subgroup), B – using the proposed VR-technology of familiarization with hazardous areas (research group). A representative sample with a confidence probability of 95%, a confidence interval of 5%, and a total population of 15 people is enough to examine 14 students in each subgroup. The results of the competency input test are summarized in Table 3.

Table 3

Summary list of cadets testing

Criterion values	Group 1		Group 2	
	Subgroup A_1	Subgroup B_1	Subgroup A_2	Subgroup B_2
	14 students	14 students	16 students	15 students
«unsatisfactory»	1	1	1	2
«satisfactory»	3	2	4	3
«good»	8	10	9	9
«excellent»	2	1	2	1

According to the distribution of points, there is a normal distribution law, and the number of cadets who passed the entrance test in subgroup A1 completely coincides with the number in subgroup B1, group 1 (the condition according to which the student passed the task is a score higher than "unsatisfactory"). In group 2, such comparison provides information; in subgroup B2, 6.7% of cadets didn't pass the test. If we consider number of cadets (they have a score higher than "satisfactory"), then in subgroup B1 the indicators are 7.2% higher, and in subgroup A2 they are 2% higher due to the increased number of cadets than in B2, but this not essential. Since the normal distribution law is used, it is possible in the future to use the Student's t-test, otherwise – Wilcoxon's w-criterion.

Lecture material, description of practical work about additional video course on the interface and capabilities of NaviSailor 4000, both groups received in LMS Moodle distance learning system according to the schedule.

Cadets' evaluation of group 1 and group 2 was carried out according to the criteria of speed and accuracy of the final check assignment.

The results are summarized in Table 4.

Table 4

Summary list of cadets' assessment during the final check on the simulator NaviSailor 4000

Criteria	Criterion values	Group 1		Group 2	
		Subgroup A_1	Subgroup B_1	Subgroup A_2	Subgroup B_2
		14 students	14 students	16 students	15 students
Accuracy	«unsatisfactory»	2	0	3	--
	«satisfactory»	4	2	3	4
	«good»	7	8	10	7
	«excellent»	1	4	--	4
Speed, min.	till 40	--	1	--	--
	from 40 to 50	2	4	3	6
	from 50 to 60	11	9	11	9
	Didn't have time	1	--	2	--

The criterion of speed is not included in the overall assessment for completing a practical task, only as qualitative indicator of student's ability to make quick decisions when navigating a ship. Therefore, it is advisable to make a comparison only on the basis of "passed / failed" criterion. The student "passed" if speed was within 60 minutes (2 academic hours), and there is a grade for accuracy {"\" satisfactory \ ", \" "good", "excellent"}. Table 4 contains the value for the subgroup A1 – cadet "did not have time" and "unsatisfactory" for one person and A2 – for two people.

The results of Student's t-test calculating are presented in Table 5.6.

Table 5

Comparison of statistical data of control subgroups with experimental

Criterion values	Group 1	Group 2

	Subgroup A_1	Subgroup B_1	Subgroup A_2	Subgroup B_2
	14 students	14 students	16 students	15 students
«didn't pass»	2	–	3	–
«pass»	12	14	13	15

Table 6

Calculated data of standard deviation and Student's t-criterion

Test criterion	S_d		t-criterion	
	Group 1	Group 2	Group 1	Group 2
Accuracy	0,289 4	0,284 3	2,073	2,110

Number of degrees of freedom: 1 group – 27; group 2 – 30. For group 1: calculated value of criterion 2.073 is greater than tabular 2.052 (critical) at $p = 0.05$, but less than 2.771 at $p = 0.01$, then the significance level is less than 0.05. For group 2: value of t-criterion is 2.110 – more than tabular 2.042 (critical) at $p = 0.05$, but less than 2.75 at $p = 0.01$. It can be concluded that for both groups the differences studied are statistically significant.

Statistical analysis of research results is summarized in Table 7.

Table 7

Research results

Test criterion	Criterion values	Group 1		Group 2	
		Subgroup A_1	Subgroup B_1	Subgroup A_2	Subgroup B_2
Accuracy	«satisfactory – excellent»	86%	100%	81%	100%
Speed	till 40	--	7%	--	--
	from 40 to 50	14%	29%	18%	40%
	from 50 to 60	79%	64%	69%	60%
	Sufficient speed for positive evaluation	93%	100%	87%	100%
Didn't have time		7%	--	13%	--
Passed		86%	100%	81%	100%

4. Results and Discussion

Based on the results of experimental training using VR technology, there is better assimilation of navigator's practical skills according to research data in group 1 – by 14%, in group 2 – by 19% compared to the usual blended form of education. At the same time, there are no cadets who did not cope with the practical task.

The results can be considered significant and the experiment was successful in both groups. The proposed model of training in the direction of "Navigation" is working option for obtaining of difficult profession of navigator.

The advantages of using VR technology are: significant improvement in the acquisition of theoretical material and practical navigational skills in difficult weather conditions and on difficult sections of routes using virtual reality; the possibility of using such technology remotely. The disadvantage is the difficulty of developing exercises and related software due to the large amount of data for analysis (fig.2).

5. Conclusions

In order to assess the quality of the proposed model, pedagogical experiment was carried out, which fully confirmed the effectiveness of the methodological system in the educational process – all students showed high quality of training. According to the research results, quality improvement of training practical part was achieved and methodological system using VR technology for training with the corresponding hardware and software requirements was described. Further research can be to construct an appropriate system of catalogs, each of which contains a list of such dangerous areas. A student, choosing the appropriate passage, receives a list of files that must be familiarized with before the practical course on the simulator. The latest results in VR technologies can also be introduced in the future to perform actions according to the algorithm and increase the realism effect of the processes. Therefore, when using blended learning system, remote analysis of the navigator's biometric data for panic in difficult and extreme situations will be further developed. It will allow a remote assessment of cadet's confidence. To increase the sense of reality, it is also advisable to use tactile gloves Teslasuit Glove, which allow you to get the sensation of touching virtual objects and have integrated sensors that read information about the wearer's state – stress levels and heart rate. And this can be one of the elements of assessing the student's stress during completing of task.

These directions of VR technologies development in teaching can be introduced in most disciplines that require the implementation of management processes for complex systems with attention to the environment.

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