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Formation of professional competency in life saving appliances operation of future seafarers by means of online and simulation VR technologies

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Abstract. Nowadays simulation training technology is a priority method of maritime specialists' practical training in the world. The main purpose of using VR simulators within an educational process is to simulate work on real equipment in order to form professional competencies of seafarers. The article describes system of blended learning on the basis of Kherson State Maritime Academy, that includes alternation of traditional and online learning, virtual training by means of the VR technology, training on simulators. In accordance with the principles of blended learning in Academy, there was developed an author's course "Rescue boats and life rafts specialist", which aims at providing theoretical and practical training of seafarers on launching and handling the lifeboats and liferafts and, as a result, ensures seafarers' formation of professional competency "life-saving appliances operation". The article also reveals the results of an experiment with implementation of VR technologies in forming the professional competency "life-saving appliances operation". The deviation of the results in control and experimental groups was 9,8%. The effectiveness of our research was manifested in the fact that students have gained experience of practical skills before coming to the vessel and showed higher level of educational achievements in professional competency "life-saving appliances operation".

Keywords: virtual reality, professional competences, maritime specialists, LMS Moodle simulation technologies, life saving appliances, Maritime English

1. Introduction

1.1. Research relevance

Global trends in the use of digital technologies, innovative approaches to learning are leading to dynamic changes in the global educational space of higher education. The formation of an innovative space with increased change in production technologies and the introduction of complex management systems on a digital basis require continuous education of specialists and the transformation of higher education models.

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The formation of a seafarer's professional competencies has always been associated with many years of professional experience. Professional education of maritime specialists emphasizes the practical orientation of the educational process, which takes place in real practice directly on ship. The International Maritime Organization (hereinafter – IMO) has identified the need to use simulators to develop professional competencies. This requirement is enshrined in the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (hereinafter – STCW) [15] and is mandatory for obtaining the established standard of competence. Such a strict approach to the organization of the seafarers' educational process is due to the peculiarities of higher maritime education and high social need in qualitative training, their responsibility for life and material equipment. Assessment of competency level is determined by a professional standard, which defines all the functions, actions and assessment of the competencies' acquisition.

Full implementation of blended learning during the COVID-19 pandemic revealed a set of educational risks, such as reduced attention and interest in the content of educational cases and presentations, loss of understanding the dynamics of processes, awareness of problems and risks of professional activity [2, 29]. Bondarenko, Mantulenko and Pikilnyak [5], Bukreiev et al. [6], Bykova et al. [7], Cherniavskyi et al. [9], Holiver, Kurbatova and Bondar [14], Kartashova et al. [16], Kim et al. [17], Kravtsova, Zaytseva and Puliaieva [19], Krylova-Grek and Shyshkina [20], Kucher et al. [21], Osadcha et al. [26], Ponomarova et al. [30], Radianti et al. [32], Sun [36], Vlasenko et al. [40], Voloshynov et al. [41] have focused their research on finding effective learning technologies and analysis of their impact on professional development in a blended learning. It was found out that the most effective ones are the technologies of figurative imagination for the development of professional competencies in blended learning.

1.2. Related work

The use of VR simulators began relatively recently, but has already accumulated significant material for research. Thus, an analysis of the literature on recent experimental data suggests that virtual reality can ensure students' motivation and engagement, and provide higher-quality learning [1, 3, 8, 10, 18, 22, 23, 27, 28, 37, 39, 43].

The implementation of modern technologies into maritime education, including virtual reality simulators, helps to improve the effectiveness of professional competencies' formation, makes the learning process time-saving and safe, positively affects the consolidation and implementation of the accumulated theoretical material, makes the educational process motivated [23].

In the context of limited opportunities due to COVID-19, the possibilities of digital and distance learning, the functionality of VR simulators can present a new Maritime Education and Training (hereinafter – MET) paradigm in the discourse of the learning concept anytime and anywhere [17]. These processes will result in rethinking of the post-pandemic pedagogical approach, representing a mixture of full-time and distance learning [3].

The use of a virtual environment in connection with the novelty of its application requires to provide a comfortable atmosphere for working with the equipment, evaluate objectively the advantages of the work and the prospects for its use.

The latest gains in virtual reality represent a new supplement to professional education and training. The main aim of VR simulation technologies is to simulate the work with real equipment in order to form professional competencies settled in STCW [33, 34].

Simulation training is treated as a mandatory component in professional training that uses a model of professional activity in order to provide an opportunity for each student to perform this professional activity or its element in accordance with professional standards [38].

VR technology is aimed at mastering the algorithm for the formation of practical professional competencies of specialists [33]. VR includes "a wide variety of computer-based applications commonly associated with immersive, highly visual, 3D characteristics that allow the participant to look about and navigate within a seemingly real or physical world" [13]. VR is characterized by enhanced visualization effect, which allows you to feel a higher degree of immersion with the possibility of interactive interplay [31].

In experimental practice, the resources of virtual reality simulators can effectively fill the lack of laboratories, allowing to train in new conditions that provide a student with new information [31, 42].

Students often interpret virtual reality not only as a tool to gain knowledge and skills, but also as a means of fostering positive learning experiences with evidence of improved learning outcomes at higher levels of immersion [11].

VR is a technology that can interest and motivate a user, and can also help in cognitive processing and transfer of knowledge [3, 12]. At the simulation stage, the competences, necessary for the implementation of quasi-professional activities, are improved [41].

The whole complex technological process is decomposed into sublevels and operations that must be performed. According to Mirzakhmedova [24], the technology of VR training is aimed at multilevel acquisition of practical skills, and as the levels are passed, acquired skills are layered on each other in a clear sequence of formation in a real professional environment.

VR-based simulators support two learning theories – experimental and constructivism [17, 23]. Fromm et al. [12] proved that the unique possibilities of VR contain all modes of experimental learning (specific experience, reflexive observation, abstract conceptualization and active experimentation).

Simulation practice has a successful history of integration into maritime education; investment in the development of simulators is constantly growing. Thus, simulators of equipment in the bridge and engine room are nowadays used to train seafarers [9, 34, 41].

Despite the fact that maritime industry has developed a regulatory framework for training and assessing the competencies of seafarers, formation and assessment of competencies is still changing with the course of technological progress. The nature of MET is changing in the context of influence of the latest generation technologies as teaching tools [17]. As a result the questions arise: "how will online technologies of distance learning and simulators be combined?" and "what will their effectiveness and weaknesses be?"[23].

The aim of the article is to substantiate the system of professional training of seafarers by means of online and simulation VR technologies.

2. Results

The educational process at Kherson State Maritime Academy (hereafter – KSMA) is based on the system of blended learning, which provides for the integration and complementarity of such types of educational activities as (figure 1):

1) alternation of traditional and online learning, where the latter is based on the synchronous (learning in real time with the involvement of a group of students through conference programs in LMS Moodle) and asynchronous (covers individual or group work, even if participants can not be online at the same time through means of media – e-mail, chats, social networks, forums, etc.) approaches;
2) virtual training by means of the VR simulator, the purpose of which is the practical development of competencies according to a certain algorithm in a virtual environment that maximally simulates the working conditions on the ship;
3) training on simulators – maritime equipment simulators that allow you to practice professional competencies;
4) training during practical training on the ship.

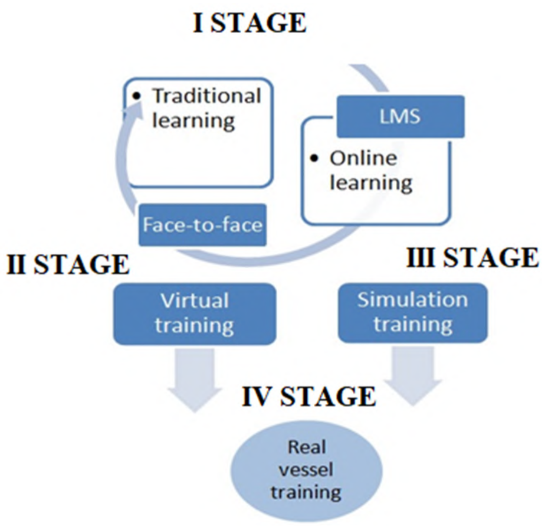

Figure 1: Scheme of educational process at KSMA.

At the first stage, in line with the theory of Staker and Horn [35] on models of blended learning, the alternation of traditional and online learning in KSMA follows due to the model of rotation, when students change the learning format from face-to-face to online and so on until a certain competency is formed. In the context of the COVID-19 pandemic, a flexible model can be used, where students study mainly online as part of e-learning modules, and the instructor provides online consultations as needed.

In the second and third stages, the learning activities correspond the mix model, when students supplement practical classes with courses on virtual reality and simulators according to a certain schedule. The prospect of developing virtual learning is its transition to the last model of Staker and Horn [35] – an enriched virtual model, where learning takes place mostly online (in the laboratory or at home) with students using VR glasses, but with the possibility of consulting an instructor if necessary.

The fourth stage of training at KSMA involves real vessel practice, which allows the practical application of acquired professional competencies in the real working conditions of future maritime specialists.

In accordance with the principles of the system of blended learning in KSMA, a series of author's courses was developed. These courses include all four stages of educational and methodological activities. One of them is the author's course "Rescue boats and life rafts specialist", which aims at providing theoretical and practical training of students on the launching and handling the lifeboats and rafts (except speedboats) during emergency accidents in accordance with the STCW Requirements VI/2, Section A-VI/2, paragraph 5 and Tables A-VI/2-1, A-III/1 (table 1) and IMO Model Course 1.23.

Table 1
STCW requirements A III/1.

Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
Operate life saving appliance	Ability to organise abandon ship drills and knowledge of the operation of survival craft and rescue boats, their launching appliances and arrangements, and their equipment, including radio life-saving appliances, satellite EPIRBs, SARTs, immersion suits and thermal protective aids.	Assessment of evidence obtained from approved training and experience as set out in section A-VI/2, paragraphs 1 to 4	Actions in responding to abandon ship and survival situations are appropriate to the prevailing circumstances and conditions and comply with accepted safety practices and standards.

In accordance with the statements of the IMO Model Course 1.23, the main purpose of the author's course "Rescue boats and life rafts specialist" is the formation of professional competency "proficiency in life-saving appliances" in accordance with the minimum standard of competency in lifeboats and rafts "Proficiency in Survival Crafts and Rescue Boats" (IMO Model Course 1.23). The future maritime specialist will gain skills in operating life-saving appliances, operating a life raft or lifeboat during and after launching. In addition, students will have knowledge of the proper use of all devices indicating location, including communications, alarms and pyrotechnics, how to provide first aid to victims.

Before starting virtual training on the topic "Rescue boats and life rafts specialist", students must have a basic level of training by means of blended learning on the following topics: "Rescue procedure", "Abandon ship procedure", "Proper use of emergency equipment", "Types of lifeboats and rafts", "How to coordinate a rescue operation", "How to operate a closed lifeboat", "Lifeboat handling", "Usage of communication devices such as pyrotechnics and signaling equipment", "Basic knowledge of first aid assistance", "Distribution of tasks and responsibilities while abandoning the ship".

Lectures, practical and laboratory classes are used to ensure blended learning at KSMA. According to Bloom's taxonomy [4], they form knowledge, understanding and application. The above mentioned topics are covered during educational process in such disciplines as "Navigation and sailing directions", "Ship handling", "Maritime English", "Electrical and radio navigation equipment", "Global maritime communications for search and rescue».

One of the important areas of work on the introduction of blended learning with elements of online learning in KSMA was the development of a digital educational environment that combines LMS Moodle (https://mdl.ksma.ks.ua/). This work allowed to create an information database of educational, methodical, scientific information on the main areas of activity. The use of modern digital technologies allows to transfer the learning process to a qualitatively new high level. At this level, the role of the student changes to an active participant in the educational process, which is directly involved in creating and managing its educational trajectory. The potential of blended education is provided by the completeness and accessibility of all academic disciplines, the relevance and possibility of interactive cooperation between a student and an instructor. That is why LMS Moodle was chosen to create e-learning modules.

E-learning modules are treated as units of online learning that cover knowledge and skills on some topics in their logical sequence. Thus, the content of a particular topic is presented in the form of a series of e-learning modules, after which the student is tested for the level of assimilation of the studied material. In addition to the text part, such modules usually use drawings, photographs, graphics, computer animations, interactive demonstrations, hyperlinks, a glossary, specialized databases, audio and video recordings of various formats.

If the e-modules provide a summative assessment as a result of the acquired competencies, the LMS ensures the assessment itself. However, the LMS is only a mechanism that needs to be filled with learning content. At the same time, e-modules make up this educational content in general. Thus, the integration of e-learning modules with LMS Moodle provides feedback between the teacher and the future maritime specialists makes the online learning process flexible and distance learning complete with the ability to assess objectively students' competencies in a COVID-19 pandemic.

E-learning modules are a supplement to the lesson, which aims not only to deepen the knowledge of maritime specialists on a particular topic, but also to increase interest in discussion outside the audience (video and audio materials on discussion topics, cases for group discussion of problematic situations, illustrations with tasks for development of critical thinking, game exercises to consolidate the material, role play of situations, collaborative projects). Teaching the same training course can be conducted by several instructors, each of whom forms his/her e-learning modules in LMS Moodle.

The author's training course "Rescue boats and life rafts specialist" has a corresponding e-learning module in LMS Moodle for 20 hours and 10 topics. Each topic includes text, audio and video materials in maritime English, accompanied by closed (controlled) and open (production) tasks with the involvement of professional terminology of the IMO Model Course 3.17. Among basic LMS Moodle tools used when creating a course there are such as "task", "test", "choice", "lesson", "forum", "URL (web link)", "chat", etc. (figure 2).

Upon the completion of each module, students undergo a current assessment in the form of

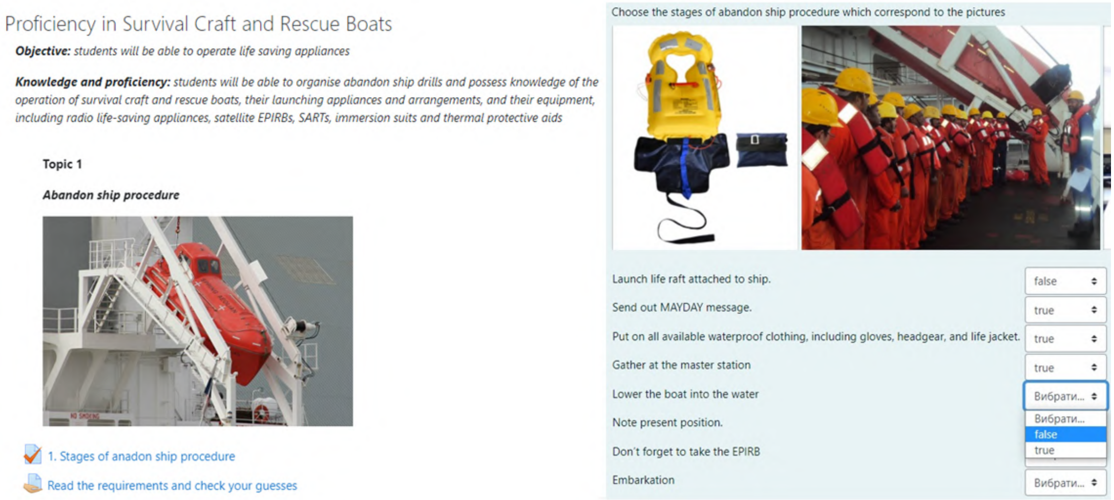

Figure 2: E-learning module in LMS Moodle.

tests and speaking exams, which allows them to advance to the next module. The exam on a specific topic is scheduled according to the Recosha meet conference program in LMS Moodle, which not only allows you to communicate online, but also records each exam, confirming its objectivity.

Upon completion of the "Rescue boats and life rafts specialist" e-course at LMS Moodle, students take a summative testing assessment of the level of knowledge gained, accompanied by a speaking competency in the format of an interview. This form of current control of knowledge simulates the conditions of passing the professional interview for future maritime specialists.

The testing tasks are constructed in such a way as to check the cluster of competencies (linguistic, functional, strategic and sociolinguistic) in their unity. If in most e-learning databases (Marlins, MarTEL, TOME, TOMEC) gradation of test tasks is carried out mainly in the categories of "listening", "grammar", "vocabulary", "reading", and sometimes "writing", then in KSMA techniques of tests and their content come from the specific context of language use, real-life communication situations on board (real-life scenarios). Separately selected grammar exercises are out of focus.

According to the results of quantitative analysis of testing techniques on the LMS Moodle platform, the most priority is taken by "multiple-choice tests" – short answers based on statements or texts, "yes / no tests" or "compliance tests" ("true / false tests") – short answers used in reading and listening, "rearrangement tests", "gap-filling tests" or "short answers" – are often used to test vocabulary and application filling skills. The above types of tests are always presented in combinations with illustrations, video and audio materials (listening – multiple-choice tests, reading – yes / no tests, watching – gap-filling), which are as close as possible to the real conditions of communication on board (figure 3).

After gaining a passing score, students are admitted to the next type of training – virtual. While completing practical tasks on the VR simulator due to the course "Rescue boats and life rafts specialist", future maritime specialists must demonstrate professional competencies using

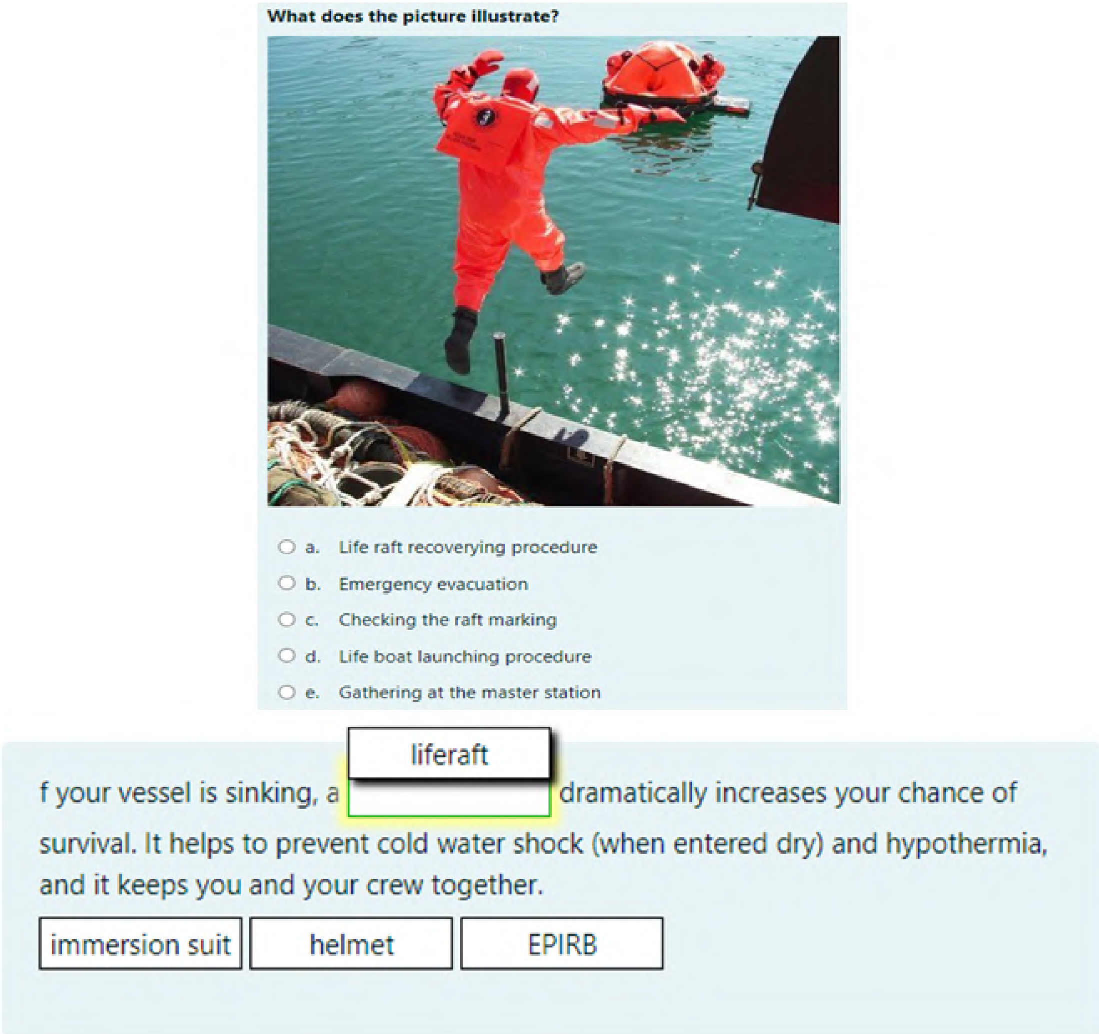

Figure 3: Testing tasks within e-learning module.

the maritime terminology of IMO Model Course 3.17: “ability to operate a boat according to a compass”, “skills of towing other boats and rafts with a lifeboat”, “approaching a lifeboat to the ship”, “use of devices to determine the location of the boat”, “use of lifeboat radio equipment”, “preparation and safe launching of lifeboats and rafts”, “abandoning the vessel within a free fall lifeboat”, “use of inflatable life raft”, “ability to operate a lifeboat on water”, “use of signaling equipment”

The content of the virtual module consists of 11 basic stages, the completion of which is necessary for successful demonstration of professional competency in launching the fully enclosed and free fall lifeboats in rough weather, following the procedures and scenarios of ship drills (figure 4).

Practical classes on the virtual simulator are held on a schedule in a specially equipped

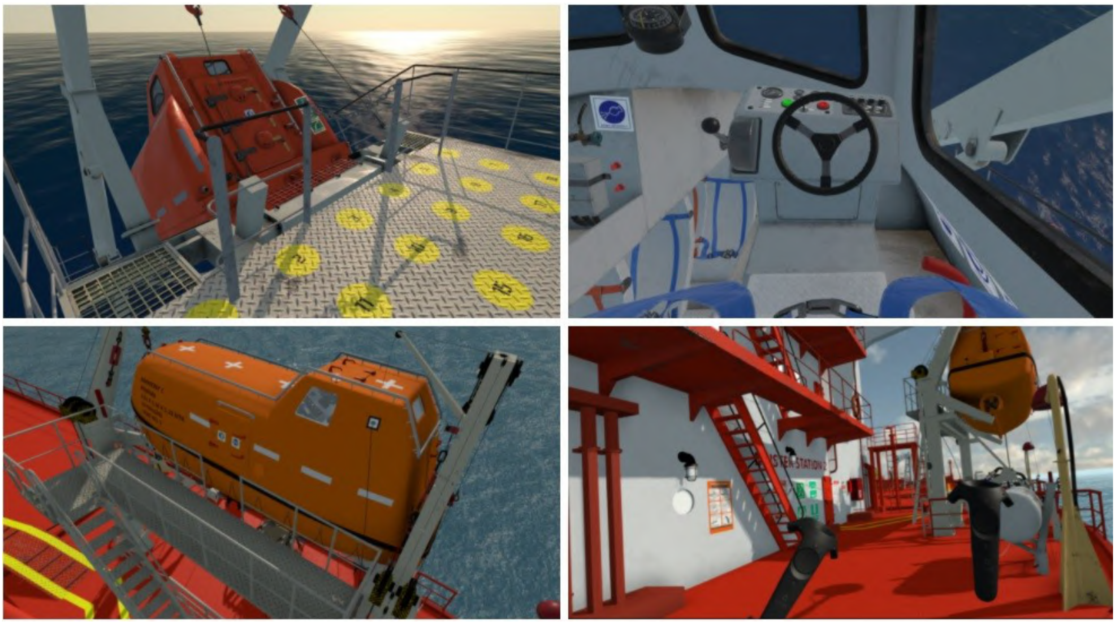

Figure 4: Virtual module "Lifeboat and Raft Specialist".

virtual reality laboratory. A small group of students (no more than 10–16 participants) joins the classes. The lesson has a flexible structure and is built on individual, pair and group format of interaction. The language of the lesson is Maritime English with the involvement of professional terminology of the IMO Model Course 3.17.

In turn, students wear VR glasses and join the process of passing the necessary stages of virtual module [25] while one of the students goes through part of the stage (for example, "Abandoning the ship in free fall lifeboat"), performing the appropriate commands in English, the other students see his actions on a big screen and work in groups or pairs, discussing each step, commenting on compliance / inconsistency of actions in this situation.

One of the advantages of practical classes in such virtual environment is the endless number of attempts and the simulation of real conditions for passing ship's drills.

Training on simulators at KSMA takes place in 13 training laboratories that meet the requirements of IMO and STCW Convention 78/95. Within the author's course "Rescue boats and life rafts specialist" 3 training laboratories are involved: "Survival at sea and fire fighting training complex", "Life saving appliances onboard a vessel" and "Global maritime distress and safety simulator".

Thus, training laboratory "Survival at sea and fire fighting training complex" contains a water pool for practicing water rescue and helicopter rescue skills, a fully enclosed lifeboat (figure 5). All works on the installation of equipment for the training complex was performed by the Irish company SEFtec. This laboratory allows students to acquire practical skills in the course of training in personal survival at sea, first aid, personal safety and social responsibilities in accordance with national requirements and the requirements of the International Convention STCW 78 with amendments, requirements VI / I, requirements of IMO Model Courses 1.13, 1.19, 1.20, 1.21.

Figure 5: Training laboratory "Survival at sea and fire fighting training complex".

3. Results

The research was held on the basis of the KSMA, a training complex and classrooms with virtual simulators. 211 students of the II course and the II course (abridged program) of the speciality "Navigation" and 14 teachers took part in the experiment. It was conducted special survey, questionnaire and testing.

The program of the research included: checking the level of professional competency formation "lifesaving appliances operation"; preparing the tool for diagnostics professional competence; creating methodical recommendations for the VR simulator on the basis of KSMA; statistical analysis and theoretical analysis of the research result.

To solve the highlighted tasks, we used the set of scientific methods:analysis of materials received on the basis of research, also: questionnaires, diagnostic tests; monitoring students' work in the ordinary classrooms and in the classrooms with VR simulators, as well as taking into account the development of a motivation as for using virtual technologies; the questionnaire and testing was carried out to check the level of professional competency in lifesaving appliances operation.

The first stage of our research was to check if the students have proficiency in life-saving appliances. We made diagnostics of professional competence in lifesaving appliances operation.

Also on the first stage we wanted to understand if control and experimental groups are statistically equal. In the process of research, we used different tests to check each element of professional competence (understanding all commands in Maritime English, connecting the painter, pulling out the pin of the slip hook, releasing the davit arm stopper by operating the handle, pulling out the safety pin of the davit arm stopper, opening the lifeboat door, switching all lights, closing engine hatch, starting the engine, connecting the davit operating grip to remote control wire). To check understanding commands in Maritime English we used Maritime English Test, to check how students can connect the painter of survival craft we used check-list to verify the correct actions, etc.

The assessment of each check-list was conducted with a help of 100 points degree. In the control group there were 103 students and in the experimental group there were 108 students. The results of the diagnostics showed that the average number according to each element of the professional competence in lifesaving appliances.

So the results have shown the low level of students' educational achievements. To check the deviation of statistical difference between control and experimental group we used Pearson criteria ($\chi 2$). Using the data we get $\chi 2$ =5.99. In result, the deviation in control and experimental groups showed that these groups are statistically the same.

On the second stage of the experimental work was conducted with our course author's course "Rescue boats and life rafts specialist". The main aims of the second stage were to check effectiveness of the course and to make analysis of data in control and experimental groups.

This author‘s course was used in experimental group. It was providing theoretical and practical training of seafarers on launching and handling the lifeboats and rafts and, as a result, ensures seafarers' formation of professional competency "life-saving appliances operation". Students got basic level of proficiency within blending traditional classes in Academy and e-modules in learning management system Moodle. Also students in experimental groups used VR simulator and additional exercises in Maritime English.

In the end of experiment we used check-lists and tests to compare deviation between two groups. The results are shown in table 2.

Table 2
Results of the assessing professional competency in life-saving appliances operation

Maritime English and Practical Demonstration	Control group (Subgroup A1) 54 students	Control group (Subgroup B1) 49 students	Experimental group (Subgroup A2) 55 students	Experimental group (Subgroup B2) 53 students
Understanding all commands in Maritime English	78	74	94	92
Connecting the painter	83	81	93	84
Pulling out the pin of the slip hook	86	85	95	85
Releasing the davit arm stopper by operating the handle	87	77	93	91
Pulling out the safety pin of the davit arm stopper	81	83	96	92
Opening the lifeboat door	83	76	94	88
Switching all lights	82	78	93	89
Closing engine hatch	78	79	89	87
Starting the engine	82	83	92	92
Connecting the davit operating grip to remote control wire	87	82	95	89
Average	82.8	79.7	93.4	88.9

The results are shown that the statistical deviation between groups is 9,8%. Students from experimental group reacted quicker and made all actions in VR simulator from the first time. It was noted that students from control group passed the VR simulator in 3 days and students from experimental group passed the VR simulator in 1 day.

Also it was conducted special questionnaire for those instructors who were in experimental subgroups (table 3).

Table 3
Questionnaire for instructors

Statements	Answers: fully agree	Answers: neither agree nor disagree	Answers: disagree
Students understand the learning objectives in the beginning of the experiment	88	12	0
Students were highly motivated to work with VR technologies	97	3	0
The level of Maritime English was improved	81	17	2
Students were active during the lessons involving VR technologies	83	11	6
It was time-consuming to conduct lessons involving VR technologies	3	10	87

The results of questionnaire showed that instructors noticed student‘s understanding of all learning objectives. Students were motivated to work with VR technologies. Instructors stated that the level of Maritime English was improved as students had additional tasks to practice professional competency in lifesaving appliances operation. Also students were active during the lessons which involved VR technologies and instructors stated that it wasn't time-consuming to conduct the lessons involving the VR technologies.

4. Conclusion

The results of the research showed that implementation of VR technologies in forming the professional competency in lifesaving appliances operation within the author's course "Rescue boats and life rafts specialist" was "a must" innovation. VR training enabled seafarers with high motivation and interest providing deep immersion into virtual environment resembling the real ship conditions of work. Pair and group format of VR training classes resulted in active speaking and describing every step on a virtual reality ship.

Research reveals that range of the results in control and experimental groups is 9.8%. But the instructors noticed that students were highly motivated to practice with VR technologies. The effectiveness of our course "Rescue boats and life rafts specialist" was manifested in the fact that students have gained experience of practical skills before coming to the vessel. Instructors have acquired methodological experience in conducting lessons by means of VR technologies. The research implements the interest of all participants in the educational process in objective: the relationship between an instructor and a student in the "subject – object" format replaces the "subject – subject" relationship, therefore, the relationship becomes a partnership.

The results of the study prove that online and simulation VR technologies can facilitate learning, complement existing educational approaches and provide maritime specialists with new and effective content delivery means that are highly oriented on practice.

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