Application of VR technologies in building future maritime specialists' professional competences

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Abstract

Progress of modern digital technologies enlarged the quantity of researches about implementation and usage of VR technologies in education process of higher educational establishments. The article provides analysis of best practices of simulation technologies application in maritime education. Absence of national research experience, evidence base for efficiency of new VR simulators operation leaves this issue open to be investigated in terms of researches on their performance effectiveness. The article proposes overview of advantages of VR technologies implementation aimed at building and shaping of future maritime specialists' professional competences. Authors investigate potential application possibilities of interactive and representative potential of immersion digital technologies during education process at maritime educational establishments. Problem of VR technologies integration into education and training of future seafarers is highlighted, as well as possibility to use virtual courses in the process of future maritime specialists' training. The article reveals prognostic validity of VR simulators used for building of professional competences.

Keywords

virtual reality, professional competences, maritime specialists, validity of simulator

1. Introduction

Development of innovation technologies in maritime industry and seamanship, acceleration of life pace, increase in knowledge volume, and introduction of new educational methods make modern maritime education system develop new approaches to future maritime specialists' training. Modification of maritime education according to international standards allows Ukrainian maritime specialists to be successful and competitive at world labour market.

As a rule, training of seafarers presupposes acquisition of practical skills directly onboard the vessel; it inevitably leads to risks of complications of both material and human factor. Therefore, International Maritime Organisation (IMO) made provisions for necessity of simulator-based

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training in the process of future maritime professionals' education. This requirement is stated in STCW Convention; and the Convention is obligatory to be followed by educational establishments in order to achieve the prescribed competence standard of maritime professionals [1].

Simulators of vehicles used nowadays (cars, lorries, tanks, air and space crafts) are commercially available and effective in the process of education and training [2, 3, 4, 5, 6, 7].

Simulator-based training is one of the basic methods for practical training of maritime specialists in developed countries [8].

Virtual reality technology (VR) creates simulated educational and training environment, and VR trainings allow students to shape their professional competences comprehensively and systematically [9, 10, 11, 12].

Modern hi-tech ship equipment requires specialized education and training with implementation of phantoms, replicas, simulators and simulation installations.

As international experience proves, process of education and training of future maritime professionals should be supplemented with the stage of simulator-based training.

Among the factors promoting development of simulator-based training we can find competence-based approach in education [13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28] and change of education paradigm aiming at dual [29, 30] and life-long education [31], introduction of blended learning [32, 33, 34, 35, 36].

Implementation and improvement of modern methods of professional competence building is objectively increasing demand for professionals able to use hi-tech digital equipment.

The simulator OMS-VR, proposed to the Academy for testing and approbation, became an inducement for this research. Operating out of Odessa, OMS-VR has developed a series of virtual reality based simulations covering activities that are difficult or dangerous to train in the real world. Their training library includes titles covering proficiency in survival craft and fast rescue boats, tanker cargo operations, steering gear maintenance, launching distress flares, and ballast tank inspections [37].

Besides, another inducement for research is absence of available and effective homemade simulators. It reveals the absence of methodology basis for introduction of simulators into the process of professional competences building.

Relevance of simulator-based technologies for maritime education as field of scientific knowledge and practical specialty is beyond question. At the same time, it is necessary to define actual problems of professional competences building in those areas, where implementation of simulator-based technologies is regarded to be particularly useful and will be of great importance for further development.

2. Theoretical background

Nowadays scientific community is engaged with idea of necessity of new information technologies implementation into educational process; but absence of research experience, lack of evidence base connected with efficiency of new simulators' operation leaves much to be done on investigation of these technologies performance efficiency. Due to high initial cost of equipment and software development VR technologies are slowly adopted and implemented into educational process of educational establishments of Ukraine.

Emergence and development of simulators is connected with situation simulation for military servants aimed at creation of safe training environment and it proved to be highly efficient. VR technologies then were adopted in sports [38], industry, medicine etc. It is surgery now, that is regarded to be promising direction for scientific and applied researches in the field of simulator-based training technologies [39, 40]. Korniienko and Barchi [40] states that usage of traditional education methods containing static text and illustrations is not sufficient to understand all processes in anatomy. On the other hand implementation of VR technologies allows to improve comprehension, enhance motivation and engagement of students, accelerate process of education and achieve the effect of "learning by doing". Combination of visual, audial and kinesthetic content in realistic virtual scenario is a new concept of education, which has great potential for development.

Analysis of research works on VR technologies proves their quick pace of development and further great opportunities for implementation [41, 42, 43].

Majority of scientists agree with the idea that implementation of these technologies into education process at all the stages requires much research to be done: starting from the strategy of education process modelling and its key factors and specifically up to process of evaluation and assessment of these technologies efficiency in the framework of professional competences building [38, 44, 45, 46, 47].

Radianti et al. [48] emphasizes the necessity and importance of the factor that development of strategy of VR technologies implementation into education process should be based on the existing education theories. It is connected with development and elaboration of aims of education, key motivational principles for education process and learning outcomes for every theory of education.

Quite comprehensive review of VR technologies [44, 45, 48] proves that virtual reality tools are aimed at practical skills development facilitating understanding of complex concepts for students through simulation of real situations. Diversified interactivity and flexibility is regarded to be standard for VR development platforms [41].

Majority of researchers investigating VR technologies point out further effects for education process:

1. Cost effectiveness (high accuracy of education, small amount of time, great level of virtualization and understanding, decrease of expenses for real equipment for education);
2. Transfer of behavior skills attained in VR environment into real world;
3. Potential for enhancement of learning skills in safe environment [41, 49, 50].

Effects of immersion and participation are regarded to be main advantage of VR; they enhance pace of learning. Lieze et al. [43] states that the wider sense of participation and witness, the more meaningfully VR environment is percepted. Checa and Bustillo [44] describes participation as technological matching with reality, which can be objectively evaluated. The authors proposes to engage this factor as an evaluation criteria for educational VR technologies.

Simulator-based technologies are being successfully integrated into maritime education. Simulators of ship bridge and engine room are being widely used [8, 49, 50, 51, 52, 53, 54, 55, 56].

Nowadays simulators of ship bridge and engine room have become standard and commonplace utilities for seafarers' professional competences building (TRANSAS, SEAGULL), and VR simulators are in the process of introduction and implementation into training practice [57, 58].

In May 2017, Winterthur Gas & Diesel installed its W-Xpert Full Mission Simulator for training complete engine room crews, at the Marine Power Academy Training Centre of HHM, in Shanghai, China while DNV GL held its traditional press conference at the Nor-Shipping trade fair showcasing the company's innovative vision, with attendees taking part in a virtual reality presentation [59].

Another example is company Khora, which helped the Knowledge Center to build a VR training simulation that enables students to practice dangerous work tasks in a virtual environment, recreating a situation that are hard to simulate in real life [60].

XVR Simulation in partnership with Falck Safety Services and Saphire Complete developed safety techniques in shipping enabling introduction of new training methods like virtual reality and web-based learning, as well as elaborated a concept of hybrid education. The developers combined realistic learning and simulation in virtual reality and thus reduced length of the course from seven days of traditional classroom training to four-five days of interactive, scenario based training [58].

As one of the leading suppliers of offshore gangways, Uptime International now uses VR simulators to reduce training costs for its customers [59].

Sendi [54] points out that simulation is a key strategy for improvement of all aspects related to and regulating safety at sea.

Asghar Ali Latin generates 16 advantages of maritime education and training using simulation technologies; among them: possibility to utilize different vessel types in one simulator, non-requirements for fuel and time limits during training, independence from time and space, weather conditions management, possibility to create different scenarios in order to shape definite competences [57].

Researchers of maritime education and training note that simulators are essential in learning process of future seafarers in order to create difficult environment and stressful situations aiming at prevention of unpredictable behavior in real life; they state that simulation can shorten length of a course from one year to several weeks [52, 53, 56].

Simulator-based training (SBT) allows to conduct practical training, relapsing high-risk operations to achieve automaticity of skills and operation; in such mode instructor (teacher) can let cadets make mistakes in some limits in order to visualize the consequences and to shape preventive mechanisms for such mistakes in real professional activity [52].

It is considered that SBT promotes development of professional thinking of future maritime specialists, ability to make decisions, their self-confidence through engagement of emotional state during executing interactive exercises [61, 62]. And combination of digital education technologies with gamification is regarded to be institutional tool having higher efficiency comparing to traditional mode of education [63].

Lindmark [55] points out that aims of learning in maritime education (Bloom's Taxonomy) are closely connected to the aims of STCW Code: knowledge, comprehension (understanding) and application (skills). Therefore, if first two units can be evaluated with the help of test tasks, the best way to evaluate professional competence is practical examination with the help of a simulator. Researchers state that the best option is automatic evaluation of student's actions by a simulator, having strict and clear standards and evaluation criteria described in regulatory documents [54, 55].

Before implementing simulator into maritime specialists' education and training process, it should be tested for validity issues. After analysis and introduction of new simulation VR technologies into education process, we propose to elaborate the idea of integration of VR technologies in education and possibility to apply virtual study courses in the process of future maritime specialists' education and training according to predictive validity of a simulator.

3. Results

Requirements to the process of future maritime specialists' training are outlined in the framework of international regulatory acts (prevailing over the national ones), namely STCW Convention, IMO Model Courses directing maritime educational establishments to implement and apply actively in their education and training process distant and digital technologies, e-learning procedures, as well as simuation equipment and installations.

Chapter A I/12 of STCW Convention outlines two standards of productivity: one of them is applied to simulator utilized in education and training process, the other one – to simulator utilized for competence evaluation needs.

For obtaining sailor's Certificate of Competence, obligatory to work onboard, it should be proved that the candidate meets the requirements of competences level defined for the positions, functions and levels of Chapter A II/1-7 of STCW. This fact proves that modern education and training of future maritime specialists is based on competency-based approach. The abovementioned requirement is outlined in Bachelor's Level Standard [64].

One of the ways to achive the aim is cooperation of educational institutions with companies specializing in software development for professional education. Example of such cooperation in development of e-learning and providing cloud services is collaboration of Kherson State Maritime Academy with OMS-VR Company (Odesa, Ukraine), developers of modern software actively working in the field of training and requalification of maritime specialists.

The Company has developed a set of courses (simulating ones) based on virtual reality engaging professional situations onboard, which are difficult to be trained using traditional education methods.

The Ukrainian startup is certified by Bureau Veritas and is already working with fleet management companies including Wallem, Anglo-Eastern, and Star Bulk.

Developers introduce AR/VR based training equipment and develop their own environmental math model as new Tool in MET, which allows to simulate familiarisation and accident learning cases. This kind of training involves students to accident environments with all the adrenaline shocking, visual, sound, vibra and gravity feeling. It leads to much deeper learning and incomparably more reliable exam results [37].

OMS-VR allows simultaneous connection of great number of VR stations using cloud technologies and their operation in multiuser mode (figure 1).

Application of simulator-based learning allows creation of problem-based education process, where solvation of definite situation becomes an educational task (exercise). Course of simulator-based learning is a scheduled outline of education containing aims and tasks of educational and training activity, their sequence and evaluation of performance [65].

Complex of software elements was created for education and automated check and evaluation

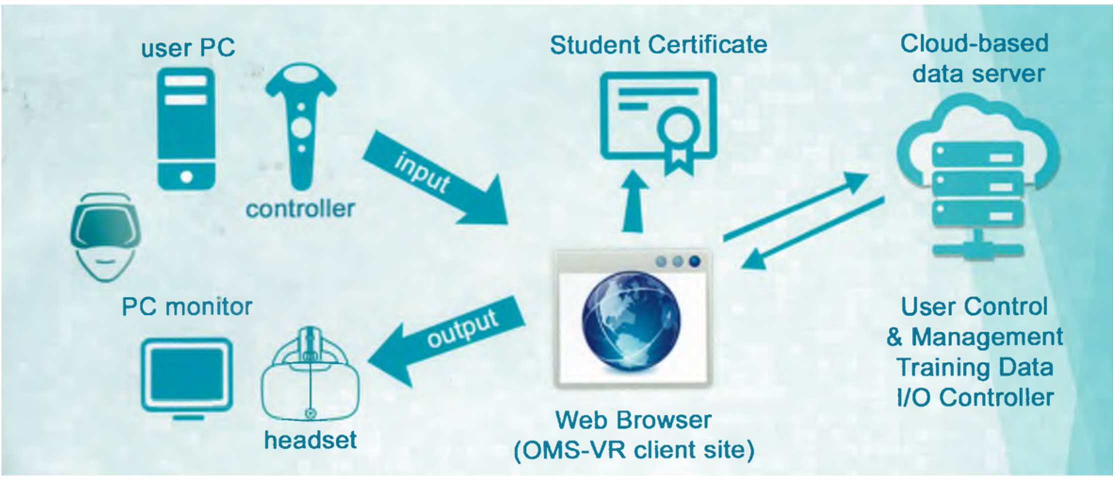

Figure 1: Layout of VR Simulator operation.

of maritime professionals' knowledge and skills; their correspondence to international and home requirements. The created virtual reality is an interactive environment – actions of user cause changes, the screen depicts movements and operations with tools. Accordingly, VR system allows simultaneous imitation of visual, tactile and audial images enhancing reality environment effect.

All virtual learning courses are launched from web-server. Information and statistical data about students' participation and performance are collected in the server in order to generate course certificates.

To start the course corresponding plugin should be launched and ammended reality glasses should be worn. Learning is done individually through immersion into professional situation. Teacher has possibility to watch and monitor student's performance, because all his actions are shown on the screen.

High level of realism is less important in the course than achievement of the set tasks aimed at professional competence building. Therefore, all virtual courses are developed according to regulatory requirements and clearly describe anticipated competences to be built at the end of the course table 1.

Every course contains training package and package for evaluation, including critical and emergency situations.

Aiming at facilitation, all actions of training package are supported with visual prompts, animation, digital and graphical elements (green in colour – figure 2). Learning and training is done according to algorythm defined in corresponding regulatory document of every course. Every stage of the course clearly demonstrates sequence of actions (accompanied by visual and audial prompts) that should be followed and done in order to perform process operation.

In the evaluation mode Report File is automatically generated after performance of definite cycle of actions for completing the task. This file contains information on objective parametres of task performance, time laps and evaluation of separate stages of process operation (figure 3).

Table 1
Virtual learning courses

№	Name	Regulating documents	Correspondence to STCW	Description of professional competences of the course
1	Training Crewmembers for Ship Helicopter Operations	Solas Convention SIRE VIQ ICS GUIDE TO Ship Helicopter Operation	Table V1-1-1	Theoretical knowledge and praktical skills for crewmembers in order to participate in merchant ship helicopter operations
2	Bulker Crane Operator	Lifting Plant and operations (COSWP), MSA CSS	Table A-V1-1-1	Theoretical knowledge and practical skills for crewmembers in order to operate bulker lifting plant safely
3	Chemical Tanker Wall Wash	IMO model course 1.03	Table A-V1-1-3	Theoretical knowledge and practical skills for crewmembers in order to comply with the requirements and procedures of Wall Wash Standard

In order to be integrated new simulation technology, as any other educational technology, has to be validated. Validation – evidence of efficiency and accuracy of education and evaluation function of a technology. If we take simulation validity, it is understood as ability to ensure higher cognitive, emotional and psychomotor skills at anticipated level with the help of achieved degree of realism [65].

To identify demonstrable and content validity we used questionnaire method in three groups of experts (experienced maritime specialists, teachers-instructors, students with induction onboard experience). Questionnaire blank contained questions developed with the help of Likert scale, which ensures relative reliability with limited number of judgements.

The results of the questionnaire revealed that no one of experts has experienced simulation learning before (100 % of respondents answered negatively). It proves the fact that there are no available VR simulators in Ukraine and, as a consequence, it proves novelty of this direction in maritime education and training.

Questions were related to virtual course Life-Boat Launching; all the experts participated in this course table 2.

There were chosen two groups of students (15 persons each). Pearson's criterion was used to prove absence of statistic deviations between control and experimental groups.

Prognostic validity defines that skills acquired during simulated training reflect the level of professional competence building in real-life environment. In order to estimate prognostic validity there was held comparison of learning outcomes of experimental group of students (virtual reality) and control group of students (KSMA Training Center). The Certificate Course "Certificate of proficiency in survival craft and rescue boats other than fast rescue boats" of Training Center has duration of 30 hours.

Control group studied theoretical module of the course using standard methodic, defined in IMO Model Course. Students of this group had two days of traditional education process in classroom with instructor in order to master theory. Students of experimental group mastered

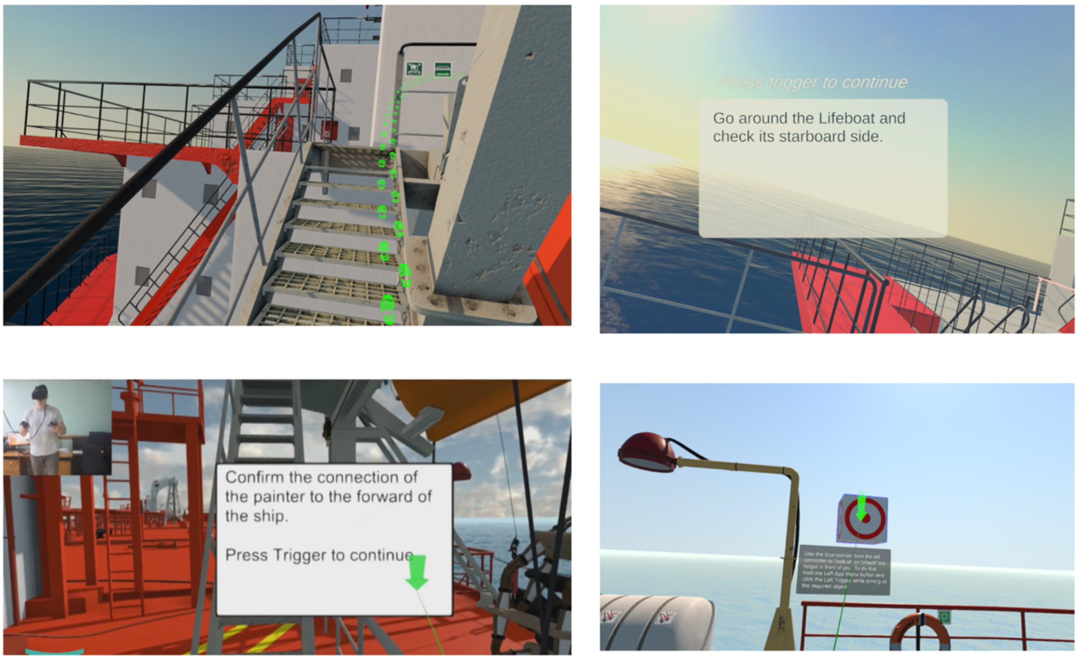

Figure 2: Examples of virtual courses.

Lesson: EPIRB and SART Assessment

ot completed

Failed - version:2019v1 Jan 27, 2021, 1:59:52 PM

Date: Wednesday, January 27, 2021 at 1:59:52 PM GMT+02:00

Center: KMSTC

Total Score: 60

Time: 7 Minutes

Performance	Status	Information - Answer	Score
Emergency Position Indicating Radio Beacon was activated correctly.	Passed		40
Emergency Position Indicating Radio Beacon was mounted correctly.	Passed		10
Search And Rescue Transponder wasn't activated correctly.	Failed		0
Search And Rescue Transponder was mounted outside the survival craft.	Passed		5
Search And Rescue Transponder was mounted to the highest point above the survival craft.	Passed		5

Figure 3: Check-list of the course.

theoretical module using VR simulator during one day. The last day of the course was devoted to training and evaluation of the acquired professional competence using real simulator “Free-Fall Lifeboat” at Water Station of KSMA.

As a result, both groups answered test questions. Assessment had 100 points scale, where 70 points is PASSED to be certified. Average point of control group was 85.09, experimental group

Table 2
Results of questionnaire on quality of training using VR simulator, %

	Captains	Students with onboard experience
How realistic is the model of the course comparing to real onboard situation?	90	78
HWhat is the degree of correspondence of actions in VR to actions onboard real vessel?	95	91
Do you think your actions would be better if they were structurally evaluated?	100	87
Is it appropriate to introduce virtual course into education process?	98	92

– 86.63. The results (check-lists) are given in the table 3.

Table 3
Results of check-list analysis

Practical Demonstration	Control group	Experimental group
The Free-fall Lifeboat was launched.	82	87
The charging cable was detached.	80	89
The charging socket was sealed with a waterproof plug.	85	87
The boarding door was fully closed during the launch.	84	92
The drain plug was sealed.	81	85
Not all valves on the air cylinders were opened.	88	83
The air supply system was activated.	85	81
The engine was running at the time of the launch.	88	92
The seat belt was worn at the time of the launch.	87	85
The Free-fall Lifeboat wasn't sailing astern after the launch.	90	91
The lights were on.	86	81
Average	85.09	86.63

Thus, control group spent three days for the course and experimental group spent two days having at the end equally high indices of acquired competence quality.

4. Conclusion

Summing up the experiment, we can state that the learning outcomes of students being trained with VR simulators do not deviate from those being taught with traditional methods. According to prognostic validity, we can prove that students of experimental group will demonstrate the level of professional competence building at the same rate when being onboard during professional routine operations. These results are provisional ones; they reveal possibility to implement VR simulation for experimental psychological and pedagogical investigations.

At the same time, they prove actuality of joint work of software developers and teachers-guidance counsellors. This work is very important for integration of two professional groups of researchers aiming at development of unified theoretical and methodical basis for providing possibility of simulators introduction into education process, development of joint terminology basis and accumulation of methodological grounding for VR simulators operation.

Taking into account the advantages of virtual reality technologies and their usage in education as well as new possibilities of digital technologies, we deem it necessary to develop these technologies in maritime education aiming at high quality building of professional competences of future maritime professionals.

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