Application of information and communication technologies and simulators to train future specialists in navigation and ship handling

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Abstract. The article presents the experience of using information and communication technologies and simulators in training future specialists in navigation and ship handling in maritime institutions of higher education. During the research a wide range of information and communication technologies and training tools were used in order to simulate scenarios of professional activity, emergency situations that are as close as possible to real conditions. The study was conducted from May 2015 to May 2019. The academic disciplines were enriched with separate components of simulator-based training for developing skills to work with electronic mapping systems, radio and electronic navigation equipment of ships, as well as skills related to maritime safety. Academic disciplines were delivered both in specialized laboratories equipped with the necessary training equipment and information and communication technologies in accordance with international requirements for training of marine specialists and the employers’ requirements, and also the training process included e-learning technologies. Comparison of research data before and after the experiment indicates a positive impact of information and communication technologies and simulators on the quality of training future specialists in navigation and ship handling.

Keywords: information and communication technologies; simulators; future specialists in navigation and ship handling; maritime higher education institutions; professional training.

1. Introduction
The need to study the use of information and communication technologies and simulators in training of future specialists in navigation and ship handling in maritime institutions of higher education is determined by a number of factors. First, in nowadays globalized world water transport, thanks to its advantages, provides about 70% of international trade, and in island countries – Great Britain, Japan and Australia – almost 100%. Second, currently the world shipping has formed an international labour market, where Ukraine, according to statistics, is among top ten countries by number of naval officers, and also one of the largest suppliers of workforce in the global labour market for seafarers. Third, the international convention on training, certification and watchkeeping of seafarers 78/95, "The Maritime Labour Convention" requires that educational institutions and shipping companies monitor the standards of training of vessel crew members based on the skills, abilities and competence demonstrated by a maritime transport specialist while working on a vessel. Also, the traditional system of training future navigators requires a significant update, because in connection to new challenges
and threats in the field of navigation in modern conditions it's mandatory to perform careful analysis of the learning outcomes – knowledge, skills, ways of thinking, values of specialists in navigation and ship handling, which they have to obtain after completing their training at the maritime institutions of higher education. Taking this into account, the use of information and communication technologies and simulators is an effective way to improve the quality of professional training of future specialists in navigation and ship handling. Information and communication technologies make it possible to present educational material in a more accessible and interesting way, present it as clearly as possible, quickly check the level of knowledge, skills and abilities of students and increase their interest in learning and mastering their future profession. The concept of "Information and communication technologies" is quite broad and general. It covers a wide range of electronic tools that are used to collect, record, store, exchange and distribute information [1]. These information and communication technologies can provide innovative ways of learning, in particular: e-learning, m-learning, u-learning, f-learning and blended-learning.

As for simulator-based technologies and complexes, their application in the training of future specialists in navigation and ship handling in marine institutions of higher education is one of the main conditions for improving the skills of marine specialists. The use of special simulators with the appropriate software, which significantly expand the scope of training, include resolving problems, malfunctions, accidents, correcting mistakes and preventing them. Fortunately, accidents are relatively rare, and therefore relevant skills and abilities associated with handling a ship in complicated (extreme, emergency) conditions are not automated in everyday professional activities. Therefore, training technologies and simulators are used to develop stable skills and abilities in emergency conditions and situations. The international Maritime Organization (IMO) has introduced simulator training in the International Convention and the Code on training, certification and watchkeeping for seafarers (STCW-78) [2]. Amendments to the IMO Convention in 1995 defined operational requirements for simulators and introduced training and competence assessment using simulators for the first time in international regulatory practice to maintain the professionalism required by part A of the Code for training, certification and watchkeeping for seafarers [2].

So, the study of the experience of using information and communication technologies and simulators in training future specialists in navigation and ship handling in maritime institutions of higher education is relevant for the theory and practice of professional education.

2. Literature review

In order to solve the tasks of the research, the actual problems of digital transformation of modern professional education presented by V. Bykov, O. Spirin, and A. Pinchuk have been taken into account [3]. Some aspects of using geoinformation resources in the educational process by visualizing educational information were studied by T. Bondarenko [4]. In the publications of Yu. Bogachkova, P. Uhan, V. Milashenko, A. Sagadina there are discussed didactic possibilities of information and communication tools for building an individual educational trajectory of the educational process participants [5]. A. Balendir et al. studied the peculiarities of using information and communication technologies for professional training of specialists [6], [7]. Important aspects of professional training of future specialists in navigation and ship handling have repeatedly attracted attention of scientists. In particular, K. Tkachenko carried out research on the problems of the system of training of water and sea transport specialists [8], M. Musorina studied formation of technical competence of future navigation specialists during the study of technical disciplines [10]. The peculiarities of using information and communication technologies in training of future navigators are covered in such publications as [11], [12].

The research methodology was based on the works of S. Voloshynov [9], who justified the ways to apply a systematic approach to the algorithmic training of navigators in an information and communication environment.
The purpose of the article is to present the results of research on the use of information and communication technologies and simulators in the training of future specialists in navigation and ship handling in maritime institutions of higher education.

3. Materials and Methods

The research uses a system of general scientific and special theoretical, empirical and statistical methods. Among the theoretical ones - analysis, synthesis, comparison - to clarify the state of development of the research problem in pedagogical theory and practice; systematization, generalization, design and modeling - to clarify the essence of the main concepts of research, justification of the possibilities of using information and communication technologies and simulators in marine institutions of higher education. Quantitative data have been obtained through the use of empirical methods, such as: interviewing, oral and written surveys, questionnaires, testing, the method of expert evaluation, the method of independent characteristics, the Stating and Forming Stages of a pedagogical experiment. These methods, utilized in the conditions of information and communication environment by S. Voloshynov [9], made it possible to find out the effectiveness of using information and communication technologies and simulators in training future specialists in navigation and ship handling. Methods of mathematical statistics (Student's t-test) have been used at the final stage of the experiment to compare two empirical distributions of the level of preparation for professional activity of respondents in the control and experimental groups after the use of information and communication technologies and simulators.

Before starting the organization of experimental work, the composition of the experiment participants was determined, and they were introduced to the tasks of the experiment. To ensure the representativeness of the sample, it was taken into account that its composition should be close to the corresponding proportions in the general population, that is, the sample should reflect the characteristics of the general population. The volume of the sample population is calculated using the formula of the 5% marginal error of representativeness:

\[ n = \frac{1}{0.0025 + 1/N}, \]

where \( N \) is the volume of the general population; \( n \) is the volume of the sample population.

The total number of participants in the Forming Stage of the experiment was 288 students who studied at the first (Bachelor's) level of higher education at the National University "Odessa Maritime Academy" and its branches – the Azov Maritime Institute and the Danube Institute.

The Forming Stage of the pedagogical experiment covered three phases: preparatory, main and final. In the preparatory phase (May 2015 – August 2015) the goals and objectives of the Forming Stage of the experiment were set, the composition of the control (CG) and experimental (EG) groups was determined, the preliminary control of readiness of future specialists in navigation and ship handling to their professional duties was organized. The CG included 143 students, and the EG included 145 of students of a Bachelor level.

During the main phase of the Forming Stage of the pedagogical experiment (September 2015 – April 2019), the appropriate changes were made to the organization of the educational process for EG students.

At the final phase (May 2019 – October 2019) - subsequent diagnostics of the state of readiness of future specialists in navigation and ship handling to professional activities among students of EG and CG according to certain criteria (cognitive and practical and their indicators) was performed.
4. Results of Research

The pedagogical experiment (conducted at the National University "Odesa Maritime Academy", including its branches – the Azov Maritime Institute and the Danube Institute) lasted from May 2015 to May 2019. Its purpose was to verify the effectiveness of using information and communication technologies and simulators.

During the study the use of a wide range of information and communication technologies and training tools was proposed for training future specialists in navigation and ship handling in Maritime institutions of higher education. The students and teachers used laptops, desktop computers, tablets, e-books, computer games, Wi-Fi networks, Internet, routers, personal digital assistants, digital cameras, video cameras, printers, scanners, radio, television, sensors, projectors, interactive whiteboards, satellite images, E-mail, messengers, video conferences, as well as various services (Google, email, social networks, telecommunications services (applications) for text messaging). All these information and communication technologies provided innovative ways to train future specialists in navigation and ship handling. For example, during the study, e-learning process was organized, which was based on the use of Internet technologies, electronic libraries, educational and methodological multimedia materials, virtual laboratories and workshops, etc.). To organize such training in an educational institution, a number of requirements were provided, in particular: access to the electronic educational environment from any device that can be identified using a username and password; the presence of a convenient format for communicating with the teacher, the ability to quickly contact and discuss issues that require clarification or in-depth explanation; presence of convenient interfaces for disciplines, individual topics and classes, tests or other forms of self-control; presence of a clear assessment system, the ability to see your progress in studying a particular issue, topic or discipline; ability to quickly find educational tasks that require urgent implementation.

Electronic documents in the form of text and image files (teaching materials; demonstration materials; collections of textbooks, training and teaching aids translated into electronic format; information in audio and video format; graphic information, etc.) were prepared for the organization of e-learning. Teachers in the Moodle system provided students with links to websites, recommendations, and instructions for studying literature.

Teachers also used email (Gmail), virtual data storage (Google drive), a Calendar application, a program for creating training courses (Classroom), and an application for conducting video meetings (Meet).

Here is an example of an e-learning process organization. Teachers who were involved in this form of learning created appropriate courses for each group of students in the Classroom application (Figure 1). The tab of each course consists of several sections – "Message Feed", "Task", "Users", "Grades". The "Users" section provides information about affiliated teachers who co-teach this discipline, as well as a list of students.

In the "Tasks" section, each teacher has the opportunity to provide relevant methodological materials and tasks that students must complete, deadlines and assessment procedure (Figure 2).

The "Assessment" section has the form of a log for monitoring students' performance of tasks with the ability to check them and make comments. To conduct online classes in oral form, we used a corporate video conferencing tool based on Google's reliable and secure global infrastructure, in particular, Meet in the G Suite for Education package. This application makes it possible not only to communicate in person during lectures, interview students in real time, but also to demonstrate presentations, check notes, monitor those present, and record the meeting on a virtual disk. An example of an online lesson fragment is shown in Figure 3.
**Figure 1.** View bookmarks of academic disciplines in the Classroom application for training future specialists in navigation and ship handling.

**Figure 2.** View bookmarks of academic disciplines in the Classroom application for training future specialists in navigation and ship handling.

**Figure 3.** Fragment of an online class using Google app with a demonstration of the presentation.

Using the capabilities of the Gmail application, information was quickly and timely communicated to all students involved in distance learning, as well as document flow in the chain between teachers, the department, and the educational and methodological department of the Institute. This application allowed not only to forward documents, but also to access the document and make comments. To save large amounts of information, we used the capabilities of a virtual data storage (Google Drive). The
capabilities of this service were used not only for storing personal information, but also for providing access to it to other participants in the process.

The resource FreeConferenceCall.com was also used for distance training. The procedure involved obtaining by students of an account, including the dial-up number and access code. The distance learning system is configured in such a way that the teacher had the opportunity to offer their own approach to the organization of training, communication and knowledge control. This approach proved to be very important for Maritime educational institutions, since students spent a long time on swimming practice and could not directly communicate with teachers and receive advice.

To implement e-learning during the study, a web-site was developed that played an important role. Its structure and content met all didactic, ergonomic and informational requirements. The distance learning web-site contributed to the effective organization of independent work of students, helped to increase the level of their educational achievements, the development of professionally significant personal qualities, creative abilities, independence and activity, thereby contributing to the formation and development of professional competence of future specialists in navigation and ship handling.

The study also used simulation technologies with augmented (AR) and virtual reality (VR), as well as 3D electronic educational systems. Since the use of real vessel handling systems is financially burdensome and carries some risk to the lives of students and damage to technical equipment, so improvement of the quality of education and practical character of educational process is possible through the use of electronic educational resources of new generation. In the work of simulators, virtual reality is mixed with augmented reality and it is a vivid example of how with the help of these latest information technologies it is possible to achieve a lasting effect of immersion in the marine realities of navigation.

In accordance with the International Convention on training and certification of seafarers and watchkeeping of 1978 [2] training of specialists in navigation and ship handling involves the use of information and communication technologies to simulate situations, which are as close as possible in reproduction of the real conditions of marine watchkeeping. Simulation modeling is the process of constructing (designing) a model of a real system in order to understand the behavior of the system or evaluate various strategies that ensure its functioning. The technology of simulation modeling provides for students to perform a variety of roles of future professional activities. The process of role interaction during simulation includes practical resolution of educational, quasi-professional and professional practical tasks, acquisition of practical experience, professional self-affirmation and further development of ideas about the range of professional functions and the range of professional tasks.

The study involved using simulation technology, which was implemented, for example, by introducing a business game, during which students were "immersed" in a specific situation, which is modeled using simulation tools or a game designer. The introduction of simulation technology in the educational process provided for the introduction of changes into the didactic system of the educational institution. It meant thorough design of the educational process organization, its goals, tasks and results of objective monitoring of the achievement of educational goals and obtained results, structural and content integrity of the educational process, reasonable use of techniques, methods, forms and means of learning, and receiving prompt feedback. For this purpose, teachers of the educational departments developed new programs of academic disciplines.

In addition to role-based interaction using simulation technology, special simulators with appropriate software were used during the experiment. They significantly improved formation of professional skills and abilities of future specialists in navigation and ship handling related to working in difficult conditions. With the development of technological and electronic innovations, work at sea has become a system with complex automated processes with multi-level connections, both in the "man-machine" mode and in the "man-man" mode. For example, modeling emergency situations during the educational process without the use of training complexes is particularly difficult, since an emergency situation is usually characterized by unexpected occurrence, unusual conditions, lack of information, the need for rapid decision-making, and the threat of catastrophic consequences. The
possibility of adequate modeling of navigation and meteorological conditions, emergencies, and practicing the interaction of the ship's crew with coastal services and other vessels has expanded the use of marine simulators in educational institutions.

During the experiment, a training course "Teamwork while on watch" was introduced, which involves modeling scenarios for the navigator and the vessel crew in extreme conditions. With regard to simulators and training complexes, the imitation modelling of situations that were reproduced as closely as possible to real conditions became possible due to the use of such marine simulators:

- a comprehensive dynamic positioning simulator consisting of a fully functional navigation bridge for dynamic positioning of the vessel (Class A DNV), a theoretical training class and a class with separate dynamic positioning stations (Class C DNV);
- global Maritime rescue communication simulator (GMDSS), consisting of two separate practical training classes;
- electronic navigation tools;
- a fully functional simulator of the engine room;
- full-featured vessel simulator with dynamic positioning system;
- training complex for practicing water safety skills and firefighting;
- simulator "Cargo operations";
- fire range;
- collective rescue equipment on board the vessel;
- ship power plants;
- medical assistance on board the ship;
- voltage equipment;
- mooring station.

Programs of practical training on simulators for cadets of various courses for mastering the skills of using the acquired knowledge have been created. The structure of the module course "Teamwork while on watch" has also been developed, the application of which involves mastering formation and development of appropriate competence from simple to complex, from working out elements to working out the entire operation, from writing theoretical bases to describing requirements, procedures and rules.

The implementation of this pedagogical condition also provided for the inclusion in the content of educational disciplines of separate components of simulator training for the formation and development of skills in working with electronic cartographic systems, radio and electronic equipment of vessel navigation, as well as skills related to safety at sea (working with fire equipment, rescue equipment, first aid on board a ship, cargo operations with heavy loads and containers, etc.). Each of these courses was delivered in specialized laboratories equipped with the necessary training equipment in accordance with international requirements for training marine specialists and the requirements of employers.

The introduction of information and communication technologies and simulators in the training of future specialists in navigation and ship handling in maritime institutions of higher education necessitated creation of scientific and methodological support for the development of professional competence of teaching staff. For this purpose, at the beginning of the first semester of each academic year, special training seminars were organized with teaching staff, where they had the opportunity to update their knowledge on the organization of professional training of future specialists in river and sea transport, the use of modern information and communication technologies, simulators and training complexes, modern means of training and knowledge control, the content of modern requirements of international and national legal documents regarding the requirements for the level of professional competence of future specialists in navigation and ship handling, etc.

Before beginning the series of seminars with the teaching staff their needs and requirements of teaching staff on issues related to the organization of the educational process in maritime training...
institutions, the potential of training complexes and simulators in the training of specialists of sea and river transport, the use of knowledge control tools in the system of ensuring quality of education, the effectiveness of modern teaching technologies and learning tools, innovative teaching methods, an order of conducting maritime practice, content of modern requirements of international and national legal documents regarding the requirements to the level of professional competence of future specialists in navigation and ship handling, etc.

While conducting training seminars with teaching staff, also were involved the representatives of employers, crewing companies "Marlow Navigation", IMEK, "Columbia Shipmanagment Ukraine", "Eurocrewing", the employees of the Ministry of Education of Ukraine, representatives of the developers and manufacturers of simulators and training systems, institutions of postgraduate education and advanced training, and leading specialists in methodology from NU, "OMA."

After completing the forming stage of the experiment, the re-diagnostic of the readiness of future specialists in navigation and ship handling to professional activity was carried out for students of EG and CG according to cognitive (knowledge formation) and practical (skills formation) criteria and their indicators.

The generalized results obtained by these criteria at the beginning and at the end of the forming stage of the experiment is presented in table 1.

Table 1. Average scores on indicators of readiness criteria of future navigators of the first (Bachelor) level of higher education to professional activity at the beginning and at the end of the forming stage of the experiment in CG 1 (n = 143) and EG 1 (n = 145).

| Criteria               | At the beginning | At the end |
|------------------------|-----------------|------------|
|                        | CG 1    | EG 1    | CG 1    | EG 1    |
| Cognitive              | 3.731   | 3.767   | 3.954   | 4.219   |
| Practical              | 3.728   | 3.712   | 3.952   | 4.268   |
| Generalized criterion  | 3.802   | 3.798   | 4.005   | 4.276   |

Comparison of values for these criteria before and after the forming stage of the experiment indicates that experimental measures for the use of information and communication technologies and simulators in the training of future specialists in navigation and ship handling have positively affected the quality of their training. So, the values of the formation of skills – indicators of the practical criterion for the preparation of future specialists in navigation and ship handling to professional activity indicate higher scores for EG students compared to CG on the ability to maneuver and control a ship in any conditions using suitable methods of finding location, as well as using modern electronic radar tools; the ability to plan a voyage and navigate in any conditions using suitable methods of laying sea and ocean routes; skills in evaluating navigation information obtained from all sources, including radar, automated radar laying tools and electronic navigation and information system complexes for the purpose of making decisions to avoid collisions and manage safe navigation of the vessel; navigation techniques in the absence of visibility.

In order to confirm the differences in the qualitative composition of the CG and EG according to the criteria for training future specialists in navigation and ship handling for professional activity, at the end of the forming experiment, the Student's t-test was applied, which serves to compare two empirical distributions (table 2).
The study, which lasted for four years, proved the effectiveness of using a wide range of information and communication technologies and training tools in training future specialists in navigation and ship handling. The experiment indicates a positive impact of information and communication technologies and training tools in training future specialists in navigation and ship handling.

Table 2. Results of the study of the formation of future navigators’ readiness for professional activity at the end of the forming experiment in CG 1 (n = 143) and EG 1 (n = 145).

| Criterion                      | Samples | Deviation from the average | The squared deviations |
|-------------------------------|---------|----------------------------|------------------------|
|                               | CG (X)  | EG (Y)                     |                        |
| Cognitive                     | 3.954   | 4.219                      | 0.056 -0.061           |
| Practical                     | 3.952   | 4.268                      | 0.058 -0.012           |
| Generalized criterion         | 4.005   | 4.276                      | 0.005 -0.004           |
| Sum                           | 11.911  | 12.763                     | -0.019 -0.077          |
| Average                       | 4.09    | 4.59                       | 0.006 0.005            |

So, the $T_{emp} = 4.086$. By special sums for a given number of degrees of freedom, we find $t_{cr} = 3.18$ in terms of significance of $p \leq 0.05$.

5. Conclusions
The study, which lasted for four years, proved the effectiveness of using a wide range of information and communication technologies and training tools in training future specialists in navigation and ship handling in order to simulate scenarios of professional activity and actions during emergency situations that are as close as possible to real conditions. During the pedagogical experiment, the content of academic disciplines and methods of their study included separate components of simulator-based training for the formation and development of future specialists in navigation and ship handling of skills to work with electronic cartographic systems, radio and electronic navigation equipment of ships, as well as skills related to maritime safety. Training in specialized laboratories equipped with the necessary training equipment and information and communication technologies in accordance with international requirements for the training of marine specialists and the requirements of employers proved to be effective. Training of future specialists in navigation and ship handling using e-learning technologies also proved to be effective. Comparison of research data before and after the experiment indicates a positive impact of information and communication technologies and simulators on the quality of training of future specialists in navigation and ship handling.

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