Weather Routing Software for academic purposes: A pilot study

Marcella Castells-Sanabra[a*], Clara Borén[b], Manel Grifoll[c], F.X. Martínez de Osés[d]

[a, b, d] Department of Nautical Science and Engineering
[c] Department of Civil and Environmental Engineering
Barcelona School of Nautical Studies (FNB), Barcelona, 08003, Spain.
Universitat Politècnica de Catalunya – BarcelonaTech.
[*]Corresponding author. E-mail: mcastells@cen.upc.edu.

Keywords: Maritime Education and Training (MET); Seafarers' Training, Certification and Watchkeeping (STCW) competences; Weather Ship Routing; Marine Environmental impact; Technological Impact

ABSTRACT

Academic research has focused on weather ship routing optimization through pathfinding algorithms which take into account the meteo-oceanographic forecasts (i.e. wind, waves or currents predictions). Therefore, an academic software package (named SIMROUTE) for ship routing optimization oriented to students and cadets has been developed to be used as a distance learning platform in Seafarers' Training, Certification and Watchkeeping (STCW) competences-based Maritime Education and Training (MET). The pedagogic purpose of this software package is to provide skills of ship routing optimization, to assess the impact of the meteo-oceanographic on ship navigation and to highlight the relevance of ship routing in terms of sailing time, fuel consumption and harmful emissions for the environment. This contribution summarizes the results of the pilot case identifying the strengths and weaknesses through students' questionnaire. The conclusions may help to provide distance learning in newly educated seafarers and to implement a very novel software in the framework of teaching innovation in MET institutions.

1. INTRODUCTION

Distance education is a generic term for modes of education in which the student and the teacher are separated in time and space. It includes online education (with more than 80% of online content) and blended education (with 30-79% of online content) [1]. Previous research analyses the concept of distance learning as additional modes of acquiring knowledge and skills in maritime education [2, 3, 4, 5, 6]. In this sense, new amendments of the Seafarers' Training, Certification and Watchkeeping Code (STCW) [7], as a part of mandatory training, endorsed modern methods of seafarers' education and training and mentions two options in "Guidance regarding training and assessment" (Section B-I/6): (i) in-service training and (ii) distance learning and e-learning. Then, distance learning and e-learning may be approved by the contracting parties considering the standards of training and assessment set out in section A-I/6 of the STCW Code [8]. Moreover, IMO model course 6.09 [9] specifies several remote teaching methods such as Computer-Based Teaching (CBT) and distance learning. However, neither STCW nor IMO model courses give guidelines on how CBT and distance learning can

be applied and provides a simple list of requirements for implementation. [10] shows the process of how to develop a distance education program in competence-based MET. Nowadays, some MET institutions, shipping companies, non-government organizations, classifications societies and maritime training centers have been involved in developing distance educations programs in MET and providing some training courses by distance education. Following the introduction section, this paper continues with the methodology carried out to design and implement a new e-learning course identifying which STCW competences could be assessed. Afterwards, results of a pilot case study based on exercises and questionnaires in a course of the "Master Degree in Nautical Engineering and Maritime Transport" at Barcelona School of Nautical Studies (FNB-UPC, Spain) are presented and discussed. Finally, the article ends up with some conclusions drawn from the findings and observations of this research.

2. METHODS

Firstly, this contribution deals with the design of the course structure and e-learning material based on the development of a software (named SIMROUTE) which provide an optimized route in function of the ocean-meteorological conditions considering a port origin and a port destination. The SIMROUTE system is described in detail in [11, 12, 13, 14, 15] and is based in the implementation on the A* pathfinding algorithm which optimize a cost function that is the time sailed. A* algorithm solves problems by searching among all possible paths to the goal for the one that incurs the smallest cost (shortest time) and among these paths it first considers the ones that appear to lead most quickly to the goal. The algorithm also includes a formula to calculate the ship speed reduction due to waves and the final speed is computed in function of the non-wave affected speed plus a reduction of the wave parameters.

For instance, the minimum and optimized routes are presented and compared in Figure 1 for the case example of Barcelona – Taranto route under stormy conditions as a SIMROUTE output. Additional information is provided such as the maximum wave height sailed, the fuel consumption or the carbon dioxide emission. In parallel, comprehensive documentation and material is presented as a guide for teachers, instructors and cadets.

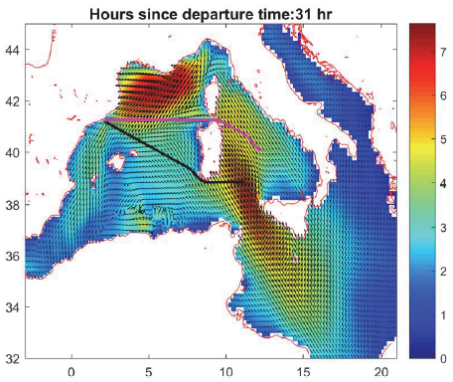

Figure 1. Minimum distance route (black line) and optimal route (magenta line) from Barcelona to Taranto on 18/12/2016. Color bar represents wave height (in meters).

Secondly, from an academic point of view, this software deals some specific topics that are part of syllabus of Maritime Education Training (MET) institutions' programs and included in

STCW 95/2010 Code. An inventory is carried out identifying which of these topics are part of the knowledge of the STCW competences (Column 2 of part A: competences tables of STCW Code). Then, the preliminary exercises are tested "on class" as a pilot study in a course of the "Master Degree in Nautical Engineering and Maritime Transport" at Barcelona School of Nautical Studies (FNB-UPC, Spain) and also some lecturers' feedback is obtained from Chalmers University of Technology (Sweden) as a part of the IAMU development project FY2018 entitled "Development of a weather ship routing software for academic purposes". The pilot study is based on online exercises divided into two specific modules and all the participating students (a total of 24 students) completed individual questionnaires before (pre-testing) and after (post-testing) the exercises. The pre-testing questionnaire is based on general questions related on WSR knowledge and programming languages used before the pilot study and the post-testing questionnaire is based on the use of the SIMROUTE algorithm and the knowledge and competences acquired during the pilot study course. With the data gathered some conclusions are drawn to provide preliminary results of the pilot study identifying strengths and weaknesses.

3. COURSE STRUCTURE AND E-LEARNING MATERIAL

Course structure has been designed into two specific modules: (1) Ship Weather Routing (SWR) application module (software familiarization, forecast weather and oceanographic conditions, software feasibility) and (2) Marine Environmental (ME) module (methodology and calculation of ship emissions). The main objective of the first module (SWR module) is to get the students acquainted with the software and point out the importance and impact of meteo-oceanographic variables in terms of sailing time comparing the minimum distance route and the optimized route. The main objective of the second module (ME module) is got when the students acquainted with the methodology of the SIMROUTE software used for calculating emissions and assess the relevance of ship routing in terms of fuel consumption and harmful emissions for the environment. In this sense, two manuals have been developed: (i) the SIMROUTE User's Manual explains step by step the operation of the SIMROUTE software designed for maritime route optimizations and (ii) the SIMROUTE Technical Manual, a compendium of the technical notes based on specific formulations and methods. Moreover, a set of step-by-step test cases with video-tutorials and the development of a full set of exercises for each module (with a gradual increasing difficulty) have been designed to ensure e-learning. The academic software package for ship routing optimization course, with exercises and all comprehensive documentation material has been incorporated into IAMUs e-learning platform (http://iamu-edu.org/moodle) for maritime instructors and cadets (see Figure 2).

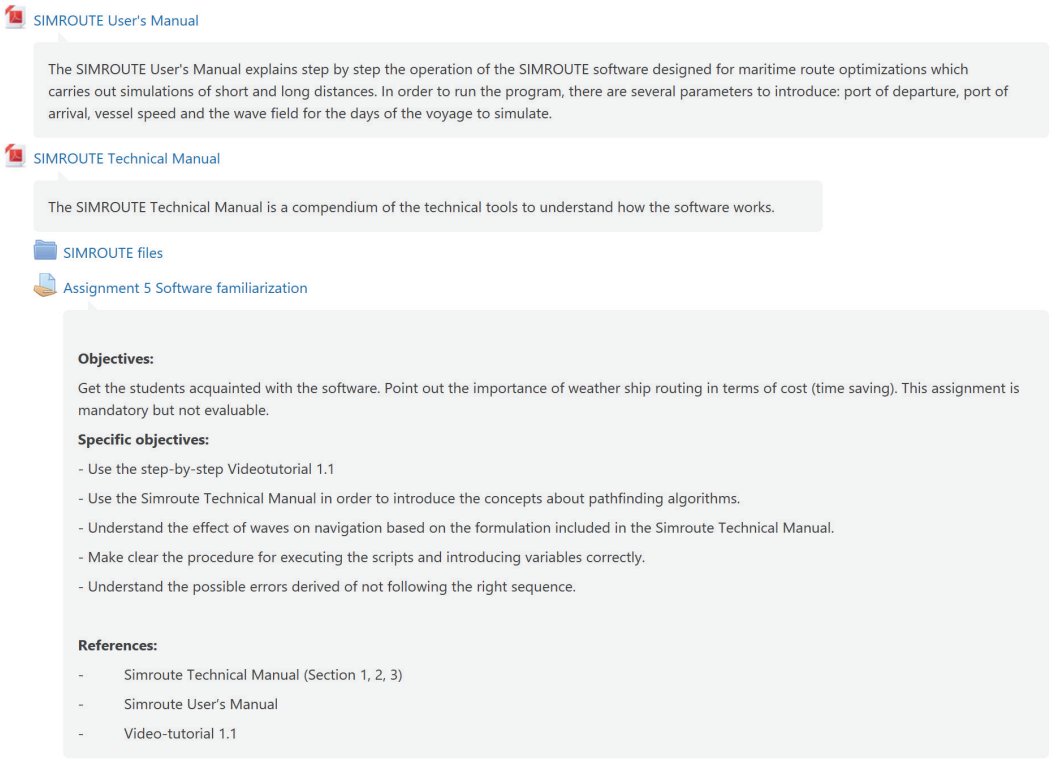

Figure 2. Screenshot of the SIMROUTE course at the e-leaning platform

4. STCW COMPETENCES

These academic modules meet with the requirements of the STCW 95/2010 Code and the proposed e-learning course can provide an excellent tool oriented to satisfy specific topics in all Maritime Academies and Universities related to STCW competences. Table 1 links topics dealt on SIMROUTE software with the mandatory minimum requirements for certification knowledge of STCW competences of Table A-II/1, Table A-II/, Table A-III/1, Table A-III/2 and Table A-III/6.

Table 1. Relation of deck and engine department STCW competences with the SIMROUTE modules

STCW competence (Column 1)	STCW Table	Module
1. Plan and conduct a passage and determine position	A-II/1	SWR
2. Maintain a safe navigational watch	A-II/1	SWR
3. Ensure compliance with pollution - prevention requirements	A-II/1 & A-III/1-6	ME
4. Plan a voyage and conduct navigation	A-II/2	SWR
5. Maintain safe navigation through the use of information from navigation equipment and systems to assist command decision	A-II/2	SWR
6. Manoeuvre and handle a ship in all conditions	A-II/2	SWR
7. Monitor compliance with legislative requirements	A-II/1 & A-III/1	ME
8. Monitor and Control compliance with legislative requirements to ensure safety of life at sea, security and the protection of the marine environment	A-II/2 & A-III/2	ME
9. Forecast weather and oceanographic conditions	A-II/2	SWR

We found that part of the knowledge of 9 competences out of all the ones described in the first column of STCW may be evaluated using SIMROUTE software. Most of the knowledge is

from master and deck department competences and only competences 3, 7 and 8 from Table 1 have the same knowledge for deck and engine departments.

5. PILOT CASE

The pedagogic purpose of this software package is to provide skills on marine environment, safety of navigation, ships routing, meteorology and navigation equipment, specific topics included in all syllabus of MET institutions' programs and also in STCW competences. Bearing in mind the existing study programmes at Barcelona School of Nautical Studies (FNB) of Universitat Politècnica de Catalunya (Spain) that includes the knowledge of STCW competences described in Table 1, and that the master has ultimate responsibility for the safety and security of the ship, its passengers, crew and cargo, and for the protection of the marine environment against pollution by the ship, the two academic modules have been incorporated in the Master's degree in Nautical Science and Maritime Transport Management to create new syllabus as a pilot study to assess the successfulness on real teaching course. A pre-testing of a questionnaire survey was conducted to assess the clarity of the questionnaire and the suitability to the students. Results of this pre-testing showed that 73% of 24 students had spent time onboard (as a cadet or as an officer) and many of them knew and could describe correctly what weather ship routing optimization is but only 4.5% were familiar with the programming language used in SIMROUTE software. After the e-learning course, many of the students agree that they feel comfortable using SIMROUTE software thanks to the manuals and specifically with the video-tutorials, being really helpful in order to understand step-by-step exercises and to execute the program's scripts. Moreover, Table 2 shows which STCW knowledge has been acquired by students after the pilot case course.

Table 2. STCW knowledge acquired by students after the e-learning course

STCW competence (Column 1)	Knowledge (Column 2)	Acquired
1. Plan and conduct a passage and determine position	Thorough knowledge of and ability to use nautical charts, and publications, such as sailing directions, tide tables, notice of mariners, radio nav. warnings and ship's routeing information	64%
	Meteorology	100%
	Ability to use and interpret information obtained from shipborne meteorological instruments	93%
	Knowledge of the characteristics of the various weather systems, reporting procedures and recording systems	93%
2. Maintain a safe navigational watch	The use of routeing in accordance with the General Provisions on Ships' Routeing	79%
	The use of information from navigational equipment for maintaining a safe navigational watch	79%
3. Ensure compliance with pollution - prevention requirements	Prevention of pollution of the marine Environment and anti-pollution procedures	93%
	Knowledge of the precautions to be taken to prevent pollution of the marine environment	93%
	Importance of proactive measures to protect the marine environment	100%
4. Plan a voyage and conduct	Voyage planning and navigation for all conditions by acceptable methods of plotting ocean tracks, taking into	86%

navigation	account	
5. Maintain safe navigation through the use of information from navigation equipment and systems to assist command decision making	Evaluation of navigational information derived from all sources, including radar and ARPA, in order to make and implement command decisions for collision avoidance and for directing the safe navigation of the ship	79%
	The interrelationship and optimum use of all navigational data available for conducting navigation	93%
6. Manoeuvre and handle a ship in all conditions	Management and handling of ships in heavy weather	93%
7. Monitor compliance with legislative requirements	Basic working knowledge of the relevant IMO conventions concerning safety of life at sea, security and protection of the marine environment	86%
8. Monitor and Control compliance with legislative requirements to ensure safety of life at sea, security and the protection of the marine environment	Methods and aids to prevent pollution of the marine environment by ships	86%
9. Forecast weather and oceanographic conditions	Ability to understand and interpret a synoptic chart and to forecast area weather, taking into account local weather conditions and information received by weather fax	79%

Finally, from the students' feedback obtained, following knowledge/modules could be introduced in the software in order to acquire additional STCW knowledge and improve the e-learning training: to introduce the possibility to change the vessel's speed in function of the vessel phase (sailing/approaching/maneuvering); to incorporate VHF Reports and TSS (Traffic Separation Scheme); to include new navigation areas using other meteorological authorities' information; to introduce more precise data in coastal navigation; to identify if the navigation area is an ECA or not and calculate emissions accordantly; to incorporate an advice with the best ETD (considering weather storm) and to incorporate a port location database.

6. CONCLUSION

The academic modules presented in this paper meet with the requirements of the new amendments of STCW Code using distance learning and e-leaning in MET and provides schools with a modern way to assess STCW competences, the distance-leaning in competence-based MET. A particular emphasis is done in terms of air emissions and safety of navigation. With the aim of charting the course for the future of maritime universities from the point of view of technological and environmental impacts, this paper provides results of the pilot study. It has been essential to identify which competences the learner will achieve, including an analysis of how many competences already gained and which still need to learn. The strengths and weaknesses have been highlighted from the post-questionnaire carried out after completing the e-leaning course and also from the Chalmers Technological University feedback. On one hand, SIMROUTE have potential to be used as a learning platform for STCW learning due to: (i) the high level of comprehensiveness of contents of the course by the students and (ii) the knowledge acquired using the proposed e-leaning teaching tool to assess some STCW competences. Nevertheless, the software and e-learning course still require some improvements to make easy the learning curve: (i) from a user perspective (nautical science

student or officer) it is difficult use the software platform and requires to be put in to a more user-friendly interface; (ii) using generic data for engine and hull effects gives a limitation if the software would be used in a real situation but can be accepted in an academic environment to describe the effect of weather on voyage planning for students. Therefore, further steps will be set into a more user-friendly graphical interface used in common weather routing software on the market today in order to be practically workable and to prepare the students for their coming work tasks in the best way.

Finally, distance learning is not popularized for mandatory certification of seafarers due to the lack of approved training facilities, approved examination and assessment systems and quality standards system to control the MET activities. Based on STCW Convention's Manila amendment laying the foundation for the application and development of e-leaning, the software package proposed in this contribution could be implemented as a new teaching model for MET institutions and could be considered as an "approved simulator training" or "approved laboratory equipment training". In this case, only competences 1, 4, 5 and 9 may be evaluated using SIMROUTE software. Nevertheless, Marine environment protection module could be introduced to reinforce this specific knowledge improving MET practices.

ACKNOWLEGEMENTS

The materials and data in this publication have been obtained through the support of the International Association of Maritime Universities (IAMU) and The Nippon Foundation in Japan.

REFERENCES

[1] Carlsen, A., Holmberg, C., Neghina, C. Owusu-Boampong, A. *Closing the gap: opportunities for distance education to benefit adult learners in higher education*, 2016, ISBN: 978-92-820-1203-1

[2] Chen, Xi., Bai, Xiangen., and Xiao, Yingjie, The Application of E-learning in Maritime Education and Training in China. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation,* 2017, 11. 163-168. 10.12716/1001.11.02.19.

[3] Bauk, S., Dñabac, T. and Pekic, Z., Implementing e-leaning modes to the students and seafarers education, Faculty of Maritime Studies in Kotor case study, *Proc. 4th International Maritime Science conference – IMSC,* pp. 19-25, 2012*,* Croatia

[4] Fletcher, S. and Dodds, W., The use of a virtual leaning environment to enhance ICM capacity building, *Marine Policy,* 2003, 27(3), pp. 260-272. doi: 10.1108/00400910810874026

[5] Hanzu-Pazara, R., Arsenie, P. and Hanzu-Pazara, L., Higher performance in maritime education through better trained lecturers, *TransNav, International Journal on Marine Navigation and Safety of sea Transport,* 2010, 4(1), pp. 87-93.

[6] Kadioglu, M., Information and Communication technology (ICT) Training Applications for MET Institutions, *TransNav, International Journal on Marine Navigation and Safety of sea Transport,* 2008, 2(1), pp. 111-116

[7] IMO, 2011, Standards of Training, Certification and Watchkeeping for Seafarers, 1978 STCW Convention), as amended, 2011 Edition

[8] Ruan, W., Views from maritime educations and training on the full implementation of 2010 STCW amendments. *Journal of shipping and ocean engineering,* 2013, 3, pp.40-46

[9] IMO, 2001, *Model Course 6.09. Training the trainees*, ISBN 978-92-801-51152
[10] Yanning, J. and Quan, L., The implication of distance learning in Competence-based Maritime Education and Training, *International Journal of Learning, Teaching and Educational Research,* 2017, 16(5), pp.31-41
[11] Grifoll, M. Ship routing applied at short sea distances, *7th International Conference on Maritime Transport, Spain,* 2016. ISBN: 978-84-9880-591-8
[12] Grifoll, M., and Martínez de Osés F. X., A ship routing system applied at short sea distances*, Journal of Maritime Research,* 2016, 3(2), 3-6.
[13] Grifoll, M., Martorell, Ll., Castells, M., Martínez de Osés F.X., Ship weather routing using pathfinding algorithms: the case of Barcelona – Palma de Mallorca, *Transport Research Procedia,* 2018, 33, 299-306. Doi: https://doi.org/10.1016/j.trpro.2018.10.106
[14] Boren, C., Castells, M., Grifoll, M. Intercomparison of emissions assessment methodologies in a Short Sea Shipping framework, *19th Annual General Assembly – AGA 2018 International Association of Maritime Universities (IAMU),* 2018, Spain
[15] Grifoll, M., Martínez de Osés, F.X. and Castells, Potential economic benefits of using a weather ship routing system at Short Sea Shipping M. *WMU J Marit Affairs*, 2018, 17: 195. https://doi.org/10.1007/s13437-018-0143-6