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Simulators in bridge operations training and assessment: a systematic review and qualitative synthesis

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Abstract This article presents a systematic review and qualitative synthesis of the use of simulators in maritime education and training (MET), with a focus on bridge operations during navigation training and assessment. The review found 34 articles published in a wide range of academic journals, displaying a global field of research consisting of three main disciplines: Maritime professionals (n = 15), Human factors (n = 13) and Education (n = 6). An important conclusion made after synthesising the results of the studies is that while the potential of using simulators in training and assessment are clear, little is known about which instructional practices would ensure valid and reliable results of simulator-based education. Since MET institutions train their students for one of the most safety-critical industries in the world, there is a need for empirical studies that explore the use of simulator-based training and assessment further to lay the foundation for an evidence-based educational practice.

Keywords Maritime education and training · Bridge operations · Simulator-based training · Simulator-based assessment

1 Introduction

Simulators have been used for training and certification in Maritime Education and Training (MET) since they first appeared in the 1950s. Hanzu-Pazara et al. (2008) describe how simulator-based training was introduced in MET with the primary intent to train navigation skills such as passage planning and the master/pilot relationship. Today, simulators are used in several parts of the maritime industry, from offshore operation training on vessels and oil rigs, involving bridge operations, cargo handling, engine control, crane operations, towing and anchor handling. Simulators are also used in ship-to-shore training, training for crane operations and vessel traffic services (VTS).

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Furthermore, the use of simulators in MET is regulated in the *Standard of Training, Certification and Watchkeeping for Seafarers* (STCW) convention that provides regulations for training in simulators as well as performance-based competency tests (Section A-I/6; Section A-I/12). The latest update of the STCW code, the Manila amendments 2010, has a greater focus on technical proficiency and the non-technical skills of team management and resource management on the bridge than previous conventions. Although the practice of using simulators is well regulated and widespread in MET, it seems few studies address the pedagogical use and benefits of simulator-based training in this domain. The overall aim of the current systematic review is to create an overview of the research field, common themes of interest, conclusions made to date and to synthesise the collective knowledge of the field at large.

While the *systematic review* methodology has been commonly used in educational practice in healthcare over the last two decades, and had a great impact of what is known as an "evidence-based practice", the use outside of medicine has been limited (Bearman et al. 2012). The benefits of doing systematic reviews are several: ideally a well-executed literature review should make studies assessable and guide the reader towards the literature. It should provide trustworthiness and accountability of the review process, opening up for the readers to make their own judgement of the quality and meaning of the evidence. Moreover, a structured review reveals conceptual and value positions that can otherwise remain hidden within the discourse of different disciplines. The *qualitative synthesis* approach was chosen since research in the field is cross-disciplinary and consists of both quantitative and qualitative research methods. It is regularly used within systematic reviews as a way of pooling different sets of data and thus gathering collective wisdom from a range of different research methodologies (Bearman and Dawson, 2013).

2 Method of the systematic review

The systematic review methodology draws on the Cochrane handbook, and the key features of conducting a systematic review in an explicit, reproducible and methodological way as presented in Bearman et al. (2012):

- A clearly defined set of objectives with pre-defined inclusion criteria for studies
- A systematic search that attempts to identify all studies that would meet the eligibility criteria
- An assessment of the validity of the findings of the included studies
- A systematic presentation and synthesis of the characteristics and finding of the included studies

The criteria for inclusion in this review are that articles should study the use of simulators for training and assessing bridge operations in MET. Furthermore, the studies should be peer-reviewed journal articles, searchable in major academic databases, available in English and published between the years 2000 and 2016.

The keywords that were used were grouped into three categories and combined during the search, following the strategy of Bearman et al. (2015). The first category included words in relation to the maritime domain: "navigation", "bridge", "ship", "marine" and "maritime". The second category contained words related to the use of simulators, but to cover all possible variations the search used "simula*". The third category of words used in the search is connected to MET: "training", "assessment" and "education". A first search was conducted by using Google Scholar, resulting in 71 found articles on simulator-based maritime training and assessment. While Google Scholar is known to include searches from student work, organisational and technical reports, journals lacking in academic credibility and so on, it was necessary to go over the results from the Google Scholar search to ensure the quality of the studies found (cf. Gehanno et al. 2013). After an initial screening, based on whether the articles meet the criterion of being published in a peer-reviewed academic journal, 41 articles remained. After reading through the abstracts and the results sections, ten more papers were excluded from the review, mainly because the scope of the paper was outside the use of simulators for training purposes (e.g., addressing simulator design questions on an algorithmic level rather than their usefulness for training). In all, 31 peer-reviewed journal articles were included in the review after the Google Scholar search.

Although Gehanno et al. (2013) concluded that the coverage of a Google Scholar search was 100 % in comparison to searches in so-called "gold standard" databases in medicine, others state that Google Scholar should never be used in isolation (e.g. Giustini, 2005). In order to ensure that all relevant studies were included in the review, the next step of the literature search involved two different libraries and two different librarians, one with focus on educational literature and the other from a technological university were guiding the search through the chosen databases: ERIC, Education Research Complete, ProQuest, Scopus, Marine Technology Abstracts and IEEE Explore. Six more items were found of which three was included in the review after screening, showing that a Google Scholar Search alone does not suffice. In the last stage of the article search, items found through recommendations were included ($n = 1$). A flow chart of the systematic search is presented in Appendix 1, and the result of the systematic search is presented with a detailed overview of the articles in Appendix 2. Table 1 is a summary of the field at large, containing information on the research domain, the methods used, geographical location, as well as a list of academic journals where the studies were published.

3 The qualitative synthesis

As the studies included in the review are both quantitative and qualitative, the systematic review is followed by a qualitative synthesis to draw conclusions on topics and themes that are recurrent in the articles and the conclusions made to date. A *narrative summary* approach to qualitative synthesis that aims to produce a selective account of the evidence was chosen, since it allows for going beyond mere description towards interpretations and reflections on a higher level of abstraction than for example thematic analyses (Dixon-Woods et al. 2005). The synthesis is organised in accordance to each of the disciplines with a section providing an insight into the nature of the studies, the major themes and foci identified in the articles, as well as reflections on their contributions towards the MET research field at large.

Table 1 Summary of the reviewed articles

		Items
Discipline	Maritime professionals	$n = 15$
	Human factors	$n = 13$
	Education	$n = 6$
Method	Experience based or theoretical	$n = 13$
	Experimental or quantitative	$n = 3$
	Mixed methods	$n = 1$
	Qualitative	$n = 6$
	Software development and testing	$n = 7$
	Survey	$n = 4$
Location	Australia	$n = 2$
	Canada	$n = 1$
	Croatia	$n = 1$
	Egypt	$n = 1$
	France	$n = 1$
	Germany	$n = 2$
	Iran	$n = 1$
	Japan	$n = 3$
	Malaysia	$n = 2$
	Norway	$n = 4$
	Pakistan	$n = 1$
	Romania	$n = 5$
	Russia	$n = 2$
	Spain	$n = 1$
	Sweden	$n = 2$
	Turkey	$n = 1$
	UK	$n = 3$
	Ukraine	$n = 1$
	USA	$n = 1$
Journal	Computers in Behaviour	$n = 1$
	Educacia, Technika–Informatyka	$n = 1$
	Education + training	$n = 1$
	Electronics and communication in Japan	$n = 1$
	Gyroscopy and Navigation	$n = 1$
	IEEJ Transactions on Electronics, Information and Systems	$n = 1$
	International Journal of Computer-Supported Collaborative Learning	$n = 1$
	International Journal of Mechanical Engineering	$n = 1$
	International Journal on Marine Navigation and Safety of Sea Transportation	$n = 8$
	International Maritime Health	$n = 1$
	Journal of Marine Technology & Environment	$n = 1$
	Journal of Maritime Research	$n = 2$
	Journal of Maritime Studies	$n = 1$
	Journal of the Human Factors and Ergonomics Society	$n = 1$
	Journal of Vocational Education & Training	$n = 1$
	Learning, Culture and Social Interaction	$n = 1$

Table 1 (continued)

	Items
Maritime Policy & Management: The flagship journal of International shipping and port research	n = 1
Maritime Studies	n = 1
Regulation and Governance	n = 1
Safety Science	n = 1
Seaways–The journal of the Nautical Institute	n = 1
Scientific Journal of Maritime Research	n = 1
Theoretical Issues in Ergonomics Science	n = 1
WMU Journal of Maritime Affairs	n = 4

3.1 The knowledge and experience of maritime professionals

As can be seen in Tables 1 and 2, a large amount of the found articles come from what was categorised as "maritime professionals". These are most often well-experienced seafarers and maritime instructors at leading positions in maritime universities, and they come from MET institutions from all over the world. It is also notable that these articles are based on knowledge of the field and experiences rather than empirical data. At times, surveys are used, but mainly in order to collect the experience and opinions of maritime professionals in a wider sense. While some of these articles provide expert advice to inform policymakers in the industry (e.g. Barsan, 2004; Barsan et al. 2007), their main contribution is something other than empirical results to inform an "evidence-based practice". They offer an insight into MET, its history and challenges, and formulates important questions that are connected both to Human factors and Education research.

Maritime professionals are most often positive towards simulators in training, yet remain concerned about the challenge that MET faces when introducing new technologies and replacing old traditions. Some of the main concerns are the upgrades of the IMO and STCW conventions and the practical impact it will have on MET. In order to ensure that future mariners can act properly and safely in practice, the conventions stress that simulators should be used for training and certification of proficiency and non-technical skills. This in turn raises a number of questions amongst maritime professionals, most commonly, if simulator-based training work in terms of improving safety at sea and reduce human error (e.g. Hanzu-Pazara et al., 2008). Another type of questions is more didactic: What would be the optimum training to ensure non-technical skills transfer? How can non-technical skills be effectively assessed on both individual and group level? What cultural factors need to be identified and addressed in training? (Pekcan et al. 2005). Also, a number of papers call for simulator technologies that are more advanced, as well as better-trained instructors, to meet these new demands on MET institutions (e.g. Ali, 2008; Hanzu-Pazara et al. 2010).

3.2 Human factors research and the usefulness of simulators in training

Human factors is a field of research that is well established in the maritime domain according to Grech et al. (2008). They describe the main interest of the field to be the human and their use of the elements in a technical system: the well-being of the human and the overall performance of the human-technology system. Hence, one central interest in human factors is to develop technologies that better fit the cognitive abilities of the user, creating safer systems for different aspects of the maritime domain. In the review, it can be seen as an interest in user testing how simulators can be designed to support different aspects of navigation training, such as ice navigation (Cemal and Burak, 2012) or precision navigation on rivers (Demchenkov, 2011). Of interest is also the relationship between simulator fidelity and the quality and transferability of training. The prevailing idea in most domains that use simulators in training is that if the simulation is close to the real-world task, the more likely it is that skills transfer from one context to another. In a case study on simulators used both in aviation and shipping, Dahlström et al. (2009) concluded that transferability of training should not rely on high-fidelity simulators alone. The primary reason for this is that is economical; it is costly to train in high-fidelity environments, and the training sessions are often designed to follow rehearsed roles, duties and procedures, and supports the development of procedural skills. Low-fidelity simulators on the other hand offer opportunities to train repeatedly for unanticipated and escalating situations, which is highlighted as important for developing resilience. Hence, based on Dahlström et al. (2009), it can be suggested that training programmes should combine the use of high-fidelity and low-fidelity simulators in their curriculum.

Another interest in Human factors is if simulator-based training works efficiently; for example, if the development of different so-called non-technical skills such as situation awareness (SA) or decision making can be trained in simulators (Saus et al., 2010, 2012; Chauvin et al. 2009). These studies use experimental and mixed method approaches to isolate and measure SA during different training conditions. The results show that the trainees subjective SA as well as the perceived realism of the training event has a positive effect on the perceived learning outcome of the trainees. Drawing on the results of Saus et al. (2010), it is important to design training procedures and scenarios that enable students to perceive the simulation as a realistic training event, and at the same time design scenarios that are well adjusted to their level of competence in order for them to benefit from the learning experience. Also, Chauvin et al. (2009) found that students that were practising SA and decision making in simulators improved in analysing complex situations. However, it is notable that students that were part of an on-board-training programme showed significantly better results that the simulator-based training group. These results are important because they point to the value of on-board-training, and call for caution before replacing on-board-time with simulator-time in MET.

3.3 Educational research on learning and learning activities

Education is a diverse scientific field with a broad interest in learning. It has been described as the "nurturing if the mental capacities through witch the learners come to know, understand, judge, reflect and behave intelligently" (Pring, 2005, p. 32). Educational research generally takes an interest in the educational activity, i.e. the transactions between teachers and learners with a focus on how the learners develop their seeing and understanding towards the object of learning. Although the search found few studies in Education ($n = 6$), the interactional approach to study learning and learning activities is dominant in the included studies that draw on ethnographic approaches to study simulator-based training and assessment in a naturalistic way. These studies highlight the complexities of considering questions of choosing the right level of fidelity for different training purposes or facilitating simulator training. When designing simulator-based training, the degree of fidelity must meet the requirements of the work tasks and learning objectives, while also attending to the specific nature of the learners' level of knowledge or expertise (Hontvedt 2015). Also, the work practices that take place on the bridge are heavily reliant on time, space and temporality in an intricate way that can hardly be simulated in an educational setting (Hontvent and Arnseth 2013). At the same time, they argue that the practice of simulator training is closely intertwined with the maritime profession's way of organising and perceiving the world. Their results support research on simulations in the healthcare domain viewing realism as an interactional matter as well as an instructional concern. Hence, simulators showed clear potential for learning, but these studies have shown that how the training is organised and carried out far exceeds the simulator.

Kobayashi (2005) studied maritime policy and documents to draw conclusions about simulators and their use for training and assessment competences involved in safe navigation and came to the conclusion that simulators are well suited for training and assessing the competencies involved in safe navigation *if* they are used properly. Studies of the actual application of simulator-based assessments point towards serious problems regarding the use of competency tests in the MET system. Emad and Roth (2008) comes to the conclusion that not only is the learning objectives not fulfilled in the MET system, the assessment system has changed the learning objectives. Instead of striving to learn the skills and knowledge required on board ships, the objective in the current MET system is to pass competency tests. In fact, Gekara et al. (2011) are warning that the haphazard ways in which assessments are currently being implemented pose a possible safety hazard for the shipping industry. Moreover, Sampson et al. (2011) discovered that maritime instructors lack knowledge and are very uncertain of how to make assessments of competency in the simulator. The results of these studies are not surprising. It is far from evident how to conduct assessment based on observation of actions in the simulated environments and the instructors' concern connects to longstanding pedagogical debates about the character of knowledge in action. Consequently, more studies are needed in order to provide guidelines for simulator-based assessments of competency to ensure validity and reliability of the assessment methods or models.

4 Conclusions and further directions

The aim of the current systematic literature review is to give an overview of the field at large, its main interests and an overview of some important findings. It should be considered a guide to the literature for its reader rather than to provide any deeper analysis on different issues, as for example the questions regarding STCW identified in the synthesis (cf. Bearman et al. 2012). Following this approach, the current systematic literature review found 34 articles published in a wide range of academic journals, displaying a global field of research consisting of three main disciplines: Maritime professionals (n = 15), Human factors (n = 13) and Education (n = 6). Hence, simulator-based maritime training seems to be a rather small and quite diverse field of research, and several of the studies found lack empirical data as a basis for analysis (n = 13). The main result of the systematic literature review is that there are more questions than answers regarding the use of simulators in bridge operation training. While initial results point towards simulators as useful for training both procedural and non-technical skills, results also point towards the need for skilled instruction during training since “the simulation far exceeds the simulator” to lend the words of Hontvedt and Arnseth (2013). It is also important to take seriously the empirical results from Emad and Roth (2008) and Gekara et al. (2011) that shows that there is potential advantages of simulator-based training and assessment, but that they are currently being poorly implemented, which poses possible safety hazards for the shipping industry. Since MET institutions train their students for one of the most safety-critical industries in the world, there is a need for empirical studies on these questions to enhance the quality of training and assessment and lay the foundation for an evidence-based practice for simulation-based training of seafarers.

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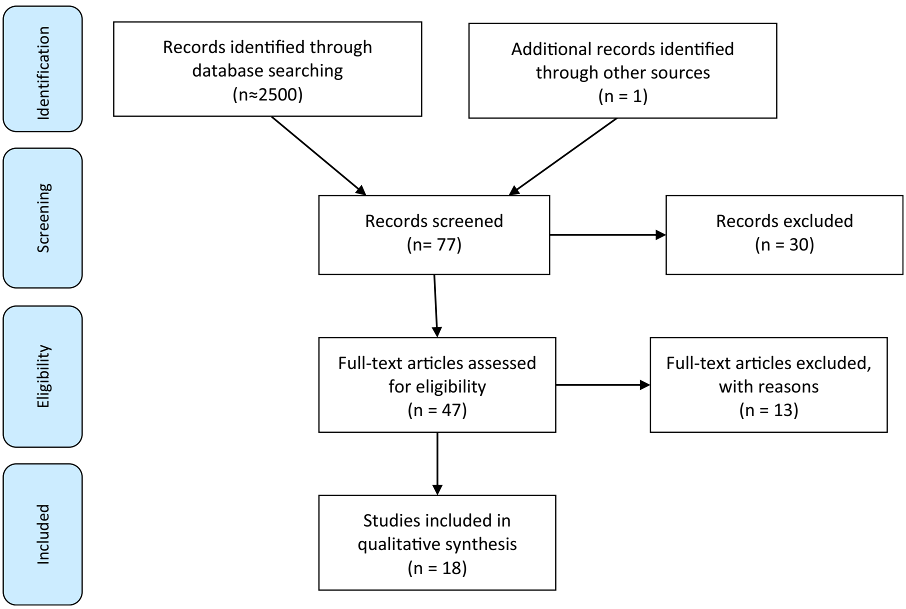
Appendix 1

Flow chart over the literature search (adapted from Moher et al. 2009).



Appendix 2

Table 2 Detailed results of the systematic review

Reference	Discipline	Research aim	Method	Main results
Aizinov and Orekov (2010)	Human factors	Exploring the need for improvement of simulators for meeting the demands of training high technology ship crews	Software development and user testing	The following trends can be seen in the development of simulator systems for the ship crews: improvement of the mathematical models, improvement of ship environment interaction models and development of interaction between various simulators
Ali (2008)	Maritime professionals	Examines the role of the instructor in simulation-based training	Survey based	Highlights the importance of the instructor as well as the need for technologies to be augmented with new measures to ensure the quality of training
Baldauf et al. (2014)	Maritime professionals	Introduces the concepts of safety and security to training in simulators	Experience based	Simulators show great potential in meeting the requirements of training of technical and non-technical skills formulated in STCW
Barsan (2004)	Maritime professionals	Explores the possibility for full mission simulator training to be equivalent to sea service	Review and analysis of different studies and maritime reports	Developed the "sea service equivalency ratio concept" to inform IMO and STCW on simulation-based training standards for training and certification
Barsan et al. (2007)	Maritime professionals	Intends to underline some of the aspects that must be revised for training in maritime education in regards to STCW updates	Analysis of maritime policy	Informing curriculum design regarding IMO compulsory courses
Benedict et al. (2006)	Human factors	Developing a "surveillance tool" and "evaluation tool" for assessment of student conduct during training sessions	Software development and user testing	The computerised assessment tools allow for in-depth search within the replay data and facilitates the calculation of

Table 2 (continued)

Reference	Discipline	Research aim	Method	Main results
				the final score for the student's performance. However, the assessment tool cannot calculate non-technical skills such as communication or SA, which has to be checked by other parameters
Benedict et al. (2009)	Human factors	Developing a tool for precision navigation and measuring its appliance to collision avoidance training in the simulator	Software development and user testing	Developing simulator technology to be better fit to train precision navigation and collision avoidance
Cemal and Burak (2012)	Human factors	Aims to analyse the effectiveness of maritime simulation systems on strengthening the maritime training for an ice navigation module	Software development and user testing	Developing simulator technologies to better fit to train ice navigation
Chauvin et al. (2009)	Human factors	Examines the impact of training programmes between simulator-based training and on-board-training regarding the ability of trainee watch officers to make decisions in collision avoidance situations	Experimental	Results showed that decision-making exercises did tend to improve the trainees' capacity to analyse a complex situation; however, they did not have a clear impact on the manoeuvre performed. There was an obvious difference between the trainees who experienced complex avoidance situations during their on-the-job training period and those who did not pointing towards the value of on-board-training in comparison to simulator-based training
Dahlström et al. (2009)	Human factors	Explores theoretical issues related to the relationship between simulator fidelity and the quality and transferability of training	Case studies of accidents from aviation and shipping	Transferability of training cannot rely only on high-fidelity simulators when work is highly complex and safety-critical. Also, lower-fidelity simulation can provide competence development with pedagogical and economic advantages

Table 2 (continued)

Reference	Discipline	Research aim	Method	Main results
Demchenkov (2011)	Human factors	Explores the use of navigational simulators for training shipmasters to control vessels on inland waterways	Software development and expert qualitative assessments of navigational simulators	Suggests the SC-method for implementing a way of evaluating the effectiveness of the navigational simulators for training shipmasters to control vessels on inland waterways
Emad and Roth (2008)	Education	Highlight the contradictions in the current MET system and to theorise the failure to make the training useful	A qualitative approach including document and policy analysis as well as ethnographic fieldwork	There are contradictions in the education and training system that do not allow the targeted objectives to be fulfilled. Fundamentally, the assessment system has changed the objectives of the education and training practises from learning skills and knowledge required on-board ships to passing competency examinations
Gekara et al. (2011)	Education	Examines the use of computer-based assessment, including simulators, for certification of seafarers within MET	A cross-cultural qualitative approach including observation, interviews and document analysis	Potential advantages of computer-based assessment. However, the design and application can be problematic and must be considered carefully. In shipping, the haphazard ways in which computer-based assessments are currently being implemented pose a possible safety hazard
Gerganov (2014)	Maritime professionals	Highlight some aspects of the use of simulators in training and assessment to improve navigation safety and reduce accidents on the ships	Experience based	The use of simulators in training will ensure the maintenance of high level of training of crews of vessels, increasing safety of navigation and reduce accidents in the Navy
Hanzu-Pazara et al. (2008)	Maritime professionals	Considers the impact on simulation-based training on maritime human error	Experience based	Training in simulators shows promising results of reducing human error caused

Table 2 (continued)

Reference	Discipline	Research aim	Method	Main results
				by improving the crisis management capability of maritime crews
Hanzu-Pazara et al. (2010)	Maritime professionals	Exploring the relationship between well-trained instructors and the level of skill of students training to be officers	Experience based	Highlighting the needs for lecturers and instructors in MET to keep up to date with advances in educational technologies
Hontvedt (2015)	Education	How are work tasks re-created and trained for in-ship simulator training sessions for maritime pilots? How is simulator fidelity related to training objectives and to the participants' professional performance of work tasks?	Interaction analysis of video data	Professional vision may conflict with an instructional strategy to isolate certain elements of the learning objective from the experience. The degree of fidelity must meet the requirements of the work tasks and learning objectives, while also attending to the specific nature of the professionals' expertise
Hontvedt and Arnseth (2013)	Education	How do students' enactment of professional roles and construction of relevant activity contexts in a ship simulator environment offer opportunities for learning and instruction?	Interaction analysis of video data	Highlights the complexities of simulating, creating scenarios, considering fidelity, or facilitating simulator training in general. The ship simulator showed clear potential for learning, but this study has shown that the simulated far 1exceeds the simulator
Ibrahim and Tawfik (2015)	Maritime professionals	Discussing how to bridge theory and practice using computers and simulators in MET	Review and analysis of different studies and technologies	Identifies questions for future research regarding the 1successfulness and effectiveness of computers and simulators in MET
Kobayashi (2005)	Education	Identifies the necessary elements and required techniques for training and assessing the competencies involved in safe navigation	Analysis of policy and documents, surveys and development of new assessment tools	Simulators are well suited for training and assessing the competencies involved in safe navigation. The application of appropriate assessment methods makes it possible to measure the mariner's

Table 2 (continued)

Reference	Discipline	Research aim	Method	Main results
				competencies quantitatively and continuously during the training period
Castells et al. (2015)	Maritime professionals	Proposes two model courses using simulators in training and assessment in accordance to the STCW Code for existing master mariners who need to revalidate their certificates	Course design and development surveys	Provides a guide for maritime training institutes for assessment in the simulator in regard to the renewing of the professional certificate for officers in charge of navigation in accordance to the STCW requirements
Malik and Zafar (2015)	Maritime professionals	Examining the pitfalls and challenges of simulator-based training in MET	Survey based	When properly used, supported by well-trained and experienced instructors, simulator training, through its risk-free environment, can contribute to a reduction in accidents and improve capability and efficiency, by providing trainees with the necessary experience and self confidence to carry out their roles, functions and tasks
Mohović et al. (2012)	Maritime professionals	Explores the problems during simulator-based training	Review	The most important task for the instructor is to create a realistic learning activity in the simulator
Muirhead (2004)	Maritime professional	Examines the impact of new technology on MET and discusses to what extent new technologies can enhance and enrich traditional practices	Survey based	Maritime institutions can benefit from the use of new technology, but only through rational planning and sustainable staged growth
Murai et al. (2010)	Human factors	The purpose is to find characteristics of body response to artificial ship movements by visual and motion platform	Experimental	Results shows that the characteristics of body response to artificial rolling and pitching by differ between different simulator platforms
Murai et al. (2011)	Human factors	Testing the fidelity of a ship handling simulator when pilots are training to enter a port, based	Software development and user testing	The results show that the visual system around the pilot's simulated ship

Table 2 (continued)

Reference	Discipline	Research aim	Method	Main results
		on the trainees' visual pattern and mental workload		promotes safe ship handling when entering a port, based on eye movement
Pekcan et al. (2005)	Maritime professionals	Describes the development of a CRM course, the theoretical underpinnings and the challenges	Course design and development	Raises theoretical and didactic questions that need to be addressed in human factors and educational research about the effectiveness of training and knowledge transfer between training contexts
Salas et al. (2006)	Human factors	A critical review on CRM and its impact on safety in different domains	Critical literature review	CRM training shows promising results. However, there are several critical needs that the CRM training community must address before CRM training can have the desired impact on safety: a mandate, access to data, and resources
Sampson et al. (2011)	Education	Explores the use of computer-based assessment methods, both computer-based multi-choice questions and simulators for certification	A cross-cultural, qualitative approach including fieldwork observations and interviews	Computer-based multi-choice questions show several weaknesses in terms of cheating. Also, they merely measure root learning. Instructors lack knowledge and are uncertain of how to conduct assessment of competence in simulators for certification
Saus et al. (2010)	Human factors	Tested the effects of experience, perceived realism and SA on the perceived learning outcome of simulator-based navigation training	Experimental	In order to enhance the learning outcomes, it is necessary to design training procedures and scenarios that enable students to achieve functional fidelity and to generate and maintain SA during training. This can further

Table 2 (continued)

Reference	Discipline	Research aim	Method	Main results
				improve safety and reduce the risk of maritime disasters
Saus et al. (2012)	Human factors	Tested the relationship between individual differences and SA during training in a navigation simulator	Mixed-methods approach	Resilient personality type predicted both subjective and observer-rated SA and managed their stress levels
Stan and Buzbuchi (2012)	Maritime professionals	To consider the vocational training of deck officers, but also the combination of simulator-based training and time at sea in the vocational system	Experience based	The vocational training is in accordance with the IMO, STCW and DNV, for training and bridge, engine and liquid cargo handling simulators
Suppiah (2007)	Maritime professionals	Exploring how simulators can bridge theory and practice	Experience based	Simulators combined with traditional lectures appear to be an effective way to facilitating learning and allow for competency to be demonstrated and assessed
Yousefi and Seyedjavadin (2012)	Human factors	Investigates the role of human factors and CRM training in minimising ship accidents at sea	Case study of maritime accidents	Seafarers need to acquire comprehensive understanding of technical facts through active learning processes that enhances deep understanding, but also to develop technical, cognitive and social skills. Skills for group/team work, good communications and re-solving issues are as essential to bridge team work

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