Advances in Human Factors of Transportation, Vol. 148, 2024, 740–748
https://doi.org/10.54941/ahfe1005266

Enhancing Scenario Design in Maritime Education and Training

Susan Harrington

University of Gothenburg, 40530 Gothenburg, Sweden

ABSTRACT

Within maritime education and training, the value of simulator-based training has long been recognized. Simulation is a powerful tool in providing students with immersive and experiential opportunities in practicing complex professional tasks in a controlled environment. In an industry where mistakes can have catastrophic consequences, the importance of providing students with an education which focuses on good seamanship, rather than simply training individual skills, is evident, with strong emphasis on training competencies such as communication, collaboration, and decision-making. Much focus in existing literature is placed upon factors such as the fidelity of the simulator and the role of the instructor during the simulation, for example, but very little has been published around the design of the scenario exercises themselves. This gap in understanding what constitutes a well-designed scenario, and the process involved in effective scenario design is addressed by this study. Semi-structured interviews have been conducted with experienced instructors from a range of institutions across Sweden, Norway, Finland, and the Netherlands. The goal of the interviews was to uncover valuable insights into the process of designing and developing scenario exercises, focusing on the key considerations that contribute to the success of such training programs. While the initial aim of the study was to develop a systematic approach to scenario design, the findings also revealed some key concerns that provide more in-depth insight into the complexity of good scenario design. Instructors emphasize the need for scenario exercises that not only mimic real-world situations, but also align with specific educational objectives. This highlights the importance of designing scenarios that accommodate the varying levels of knowledge and experience found in a group of students. The scenarios must be both concrete enough to ensure the objectives are met, and flexible enough that the instructor can cater to these individual student needs. In addition to the specific skills being trained, the scenario must be designed in a way which further embeds the non-technical skills, such as communication, teamwork, and reflexivity, central to good seamanship. Through increasing the understanding of effective scenario design, this study aims to contribute to the existing body of knowledge on simulator-based maritime education and training. The use of a recognized instructional design model, developed for training complex tasks, is recommended as complementing the existing approach taken by simulator instructors, formalizing their current practice, and providing a much-needed resource in the form of a systematic approach that captures the nuances of the instructors' experience.

Keywords: Simulator-based training, Maritime education and training, Scenario design, Instructional design

INTRODUCTION

Simulator-based training features prominently in maritime education and training (MET), where the overall aim is to equip learners with a combination of knowledge, skills, and competencies enabling them to engage in successful professional practice (cf. Bolmsten et al., 2021; Manuel, 2017). Although there has been a shift from traditional vocational training to a university-based approach to MET (Manuel, 2017), a combination of classroom-based teaching and practical experience gained through simulator-based training and time at sea is used when educating students on various aspects of seafaring, for example, navigation and bridge operations (Sellberg et al., 2018). Given the complex and safety-critical nature of professional maritime practice, it is essential that students learn to operate as part of a team of experts who can work together (Crichton, 2017), necessitating training that results in reflective expertise transferrable from the simulator environment to professional practice (cf. Dahlstrom et al., 2009; Sellberg, 2018).

Within current MET literature, simulator fidelity (cf. Hontvedt and Øvergård, 2020), the instructor's role (Sellberg, 2018), and the challenges and opportunities of simulator-based training (Kim et al., 2021) are amongst the topics addressed, but there remains a notable lack of a systematic approach to scenario design. In this exploratory study, we draw upon the use of instructional design for scenario in the similarly high-risk and safety-critical healthcare field (cf. Frerejean et al., 2023; Tjiam et al., 2012), combined with semi-structured interviews with experienced instructors, to tentatively propose a framework for enhancing current practice.

METHODS

Semi-structured interviews were conducted with 16 simulator instructors from eight institutions across Sweden, Norway, Finland, and the Netherlands. This method of interviewing was selected due its flexibility, enabling the collection of rich, meaningful data and insights (Brinkmann, 2014). The interviews were primarily conducted in person, with four taking place via Zoom due to logistical constraints. As the objective was to select a model suitable for the MET context, rather than specifically based upon instructors' current practice, this initial process of identifying a suitable instructional design model was deliberately conducted prior to in-depth analysis of the interview data. Further analysis will feature in future stages of the research. The preliminary findings from the interviews were combined with a review of current use of instructional design models in MET, and research into their use for complex learning elsewhere.

The review that was conducted utilised search terms similar to those used by Munim et al. (2023) for their systematic review of scenario design, data measurement, and analysis approaches in MET, tailored to the use of instructional design.

Search 1	(("maritime" AND ("training" OR "education") AND "instructional design"))
Search 2	(("maritime" OR "marine" OR "sea") AND ("pilotage" OR "navigation" OR "bridge" OR "seafarer") AND ("education" OR "training") AND "instructional design")

Search 1 returned 10 results, of which one was excluded as it related to ship design rather than MET design, and one was excluded due to the full text being unavailable. The remaining results were deemed recent enough not to require any filtering by year of publication, with the earliest published in 2014. Search 2 returned six results. One of these was excluded as irrelevant, as it contained the initialization "SEA" rather than relating to a maritime context. The remaining five results had also appeared in the previous search. The addition of further related terms, for example "nautical", did not change the results retrieved, so was deemed unnecessary. An overview of the eight articles included in the review can be seen in Table 1.

Table 1. Current use of instructional design in MET.

Author	Relevance
Gyldensten et al. (2023)	Discusses the mapping of student perspective and use to inform educational design. Mentions straightforward instructional design
Hontvedt (2015)	Briefing - simulation - debriefing instructional design in a training exercise for professional maritime pilots
Kandemir and Cicek (2023)	Aims to develop a decision support system for MET instructors and instructional designers selecting an appropriate instructional design model. Discusses the difficulty of making an appropriate choice for MET due to lack of guidelines
Nause et al. (2017)	Refers to the design of a distance-learning M.Sc. that has been designed to be accessible to nautical officers studying at sea. No formal instructional design model mentioned.
Nikitakos et al. (2017)	Uses ADDIE, Gagne's nine levels of learning, and Dick and Carey model for different aspects of designing and developing game-based learning for MET.
Patil et al. (2022)	Reviews literature and proposals relating to the use of AR in MET.
Shankar and Balaji (2022)	Experiential learning model used in the context of an extracurricular activity intended to measure knowledge of International Maritime Organisation (IMO)
Szwed and Rooks (2014)	Focuses on competency of cross-cultural awareness, with the objective of improving cross-cultural learning through Maritime International Exchange (MIX) program. Knirk and Gufstason instructional design model used when designing and developing the program. This had 3 stages: problem identification, program design, program development.

INSTRUCTIONAL DESIGN IN THE CONTEXT OF MET

When we refer to instructional design, we are using its definition as "*a systematic approach to the design, production, evaluation, and utilization of complete systems of instruction, including all appropriate components and a* *management pattern for using them.*" (Association for Educational Communications and Technology, 1977:172, cited in Branch and Kopcha, 2014:78). While the current approach of briefing-scenario-debriefing may be considered a form of instruction design in some regards, it does not constitute a systematic approach as per the definition, and as called for by Baldauf et al. (2012).

Just as there are varying definitions of instructional design, there are also numerous instructional design models in use. Many of these models adopt the broad ADDIE format of analyze, design, develop, implement, evaluate (cf. Branch, 2009), with each having its own strengths and limitations. As such, there is not one instructional design model that is universally "best", with the onus on the instructional designer to choose that which is most appropriate for a given learning environment (Branch and Dousay, 2015; Branch and Kopcha, 2014). In this instance, the priority is to enhance the current practice of maritime simulator instructors, rather than replacing it. This requires a model that can capture the instructors' invaluable experience, address the complex nature of MET, and facilitate the development of pedagogically-sound scenario exercises to be delivered in the existing briefing-scenario-debriefing format.

As presented in Table 1, there is no commonly accepted instructional design model for scenario design in MET, although the potential has been explored to some extent for other aspects of training. This was confirmed during the interviews, as instructors commented on designing scenarios based on their experiences, and broadly using an intuitive approach. Instructors spoke about tailoring scenario difficulty to student needs, the complexity of the tasks students were learning to perform, and the importance of this learning being transferrable to real-word practice. Clear learning objectives were a primary concern for all participants. Through a combination of this preliminary analysis, the literature review conducted, and discussion on simulator-based MET beyond the scenario design process in extant literature, we identified some key factors and requirements for selecting an instructional design model (see Table 2).

Table 2. Requirements of the selected instructional design model.

Factor	**Reason**	**Requirement**
Transfer of learning	Common theme in instructor interviews	Realistic learning environment
Complexity of tasks	High-risk, safety-critical environment requires professionals who can act appropriately in unfamiliar situations	Construction of knowledge that can be drawn upon when required
Student needs	Common theme in instructor interviews	Learning structured by increasing difficulty
Communication of expert knowledge	Difficulty in expressing knowledge that has been automated (e.g., Clark, 2014)	Ability to capture all information required for effective learning

The findings thus far make it apparent that there is a need for a systematic approach to scenario design (Baldauf et al., 2012) confirmed by interviews with instructors, and that the approach must account for the complexity of MET (see Table 2), but that current literature does not include any use of a formal instructional design model for the purposes of scenario design (see Table 1). However, simulator-based training is also used successfully in other high-risk, safety-critical fields, where formal instructional design models have been applied effectively (cf. Frerejean et al., 2023; Tjiam et al., 2012). Due to its focus on complex learning, and successful application in comparably high-risk contexts, the instructional design model we propose for use in MET is Four Component Instructional Design (4C/ID) (van Merriënboer et al., 1992), bringing a proven approach from simulator-based healthcare training to MET. Frerejean et al. (2023) recommend 4C/ID for its strengths in focusing on whole tasks, and facilitating transfer of learning, providing an illustration of how the model can be applied in training for a high-risk environment. Tjiam et al. (2012) provide more detail on conducting a cognitive task analysis to capture the expert knowledge required for successful implementation of a 4C/ID approach.

APPLYING 4C/ID TO SCENARIO DESIGN

The 4C/ID model was developed for training complex skills and reflective expertise (van Merriënboer et al., 1992). The importance of reflection within MET is recognized, and has been written about previously (Sellberg et al., 2021), and the complexity of tasks encountered by MET students is evident when we consider the definition of complex tasks as those requiring synthesis of skills, knowledge, and attitudes (Kirschner and van Merriënboer, 2008; van Merriënboer et al., 2006). The model guides educators in breaking complex tasks into four components: learning tasks, supportive information, just-in-time (procedural) information, and part-task practice (Kirschner and van Merriënboer, 2008), in a way which enhances the benefits of intuitive instructional design based on expert knowledge (Hoogveld et al., 2002, 2005), and the transfer of learning to professional practice.

The application of 4C/ID requires careful analysis of the requirements for scenario design, elicitation of expert knowledge, and eventual design of the scenario. A ten step process of implementing the 4C/ID approach is detailed by Kirschner and van Merriënboer (2008), whereby those using the model must employ appropriate techniques for capturing expert knowledge, identify and analyse cognitive strategies and mental models within the maritime domain, and use these to develop appropriate learning objectives, sequencing of tasks by increasing levels of difficulty, and setting performance objectives for assessment. Emphasis is placed upon the integration of tasks, to promote effective transfer of learning. While structuring learning in this task-centered way requires more time investment initially than simple sequencing of tasks, the integrative nature of the learning makes it more time-effective in the longer term (Kirschner and van Merriënboer, 2008). The aim here is not to design scenario exercises as quickly as possible, but to design effective scenario exercises whose performance aids in equipping students with the knowledge, skills and competencies required for good seamanship, while capturing the nuances of excellent scenario design. A simplified overview of the proposed 4C/ID approach to scenario design is provided in Table 3.

Table 3. Applying 4C/ID (adapted from Kirschner and van Merriënboer, 2008).

1. Learning Tasks
Identify the whole task to be trained. This should be a task or competency that students can expect to perform as a maritime professional e.g., navigation, ship-handling, communication procedures, or emergency response.
Break the task down into manageable chunks, creating clear, measurable, learning objectives
Draw upon real-world events requiring the performance of these tasks. The scenario should be challenging enough to be engaging without being overwhelming, and should provide learners with opportunities for practicing constituent skills
2. Supportive Information
Provide students with background information supporting the tasks, e.g., regulations, relevant theoretical concepts. This should be provided before students attend the simulator, e.g., in a lecture, or in text or multimedia format on a virtual learning environment.
Ensure that this information is integrated into the scenario to facilitate students increasing understanding in context.
3. Just-in-Time Information
Expert knowledge and real-world experience should be used to identify critical points in the scenario where students may require guidance or additional information
Provide clear, concise information at these critical points, to assist students in making informed decisions or successfully handling challenging events
This information should be made easy for students to access when needed
4. Part-Task Practice*
Break whole tasks into smaller components (part-tasks) that students can practice individually before integrating them into the practice of the whole complex task. This facilitates the automation of part-tasks that will be required regularly in professional practice, *where the whole task does not allow for sufficient practice*.
The part-tasks should first be encountered as the whole task, before being introduced for individual practice. Subsequent scenarios should include repetition of these part-tasks, increasing in complexity to allow students to gradually improve their skills.
Feedback should be provided during part-task practice to correct any errors and encourage good practice
*Part-task practice is not always necessary (Kirschner and van Merriënboer, 2008; van Merriënboer and Kirschner, 2017). It may also be inappropriate where components of a task are tightly coupled. In such cases, an alternative approach where increasing levels of complexity and diversity are introduced during whole-task practice, such as Simplifying Conditions Methodology (Reigeluth, 1999), may be required.

While selecting an appropriate instructional design model for this purpose, various elements of MET were taken into consideration, to ensure that the framework for scenario design complements the nature of education and training in the field, and preserves the benefits of the current approach, for example:

- Recognizing the instructor's own experience as being an invaluable resource and drawing upon it. The inclusion of real-life practice is essential when using the 4C/ID model.
- Social learning from peers, and from reflecting upon one's own performance.

- Designing scenarios appropriate for the students in question, that is, building upon their existing knowledge, and teaching at an appropriate level.
- Debriefing providing slightly delayed feedback, which can be more effective than that which is provided immediately (cf. Mullet et al., 2014).

The proposed approach is not intended to provide a one-size-fits-all checklist for scenario design, rather a framework for an iterative process of designing scenarios suitable for a given context.

CONCLUSION

In this paper, we have addressed the lack of a systematic approach to scenario design within maritime education and training. Following review of existing literature in the field and preliminary analysis of interviews with experienced simulator instructors, the 4C/ID instructional design model has been introduced. The focus upon training of complex tasks, and successful implementation in similar high-risk, safety-critical fields suggests that 4C/ID has the potential to be a valuable addition to the scenario design process. The approach that we have proposed recognizes the value and importance of instructors' experience and expert knowledge, enhancing rather than replacing current practice.

As simulator-based training in MET involves students working through scenarios based on real skills and competencies they will require in their professional lives, and mirroring real-life, or at least very realistic, events and situations they could feasibly encounter. An appropriate instructional design model, therefore, is one that allows the instructor to ensure that all relevant elements of the task in question have been captured and incorporated in the scenario exercise, working as a complementary addition to the tried-and-tested briefing-scenario-debriefing model. As such, the proposed approach embraces the strengths of intuitive instructional design based on extensive professional experience, while also reaping the benefits of a systematic approach.

ACKNOWLEDGMENT

This research is funded by the European Union's Horizon Europe research and innovation program under grant agreement No. 101060107.

REFERENCES

Baldauf M, Nolte-Schuster B and Schröder-Hinrichs J-U (2012) A Systematic Approach for Simulation-based Team Training in Maritime Safety. In: *INSLC 17 - International Navigation Simulator Lecturers' Conference*, Rostock-Warnemüde, Germany, 2012.

Bolmsten J, Manuel ME, Kaizer A, et al. (2021) Educating the Global Maritime Professional—a case of collaborative e-learning. *WMU Journal of Maritime Affairs* 20(3): 309–333.

Branch RM (2009) *Instructional Design: The ADDIE Approach*. Boston, MA: Springer US.

Branch RM and Dousay TA (2015) *Survey of Instructional Design Models*. 5th ed. Bloomington, Indiana: Association for Educational Communications and Technology.

Branch RM and Kopcha TJ (2014) Instructional Design Models. In: Spector JM, Merrill MD, Elen J, et al. (eds) *Handbook of Research on Educational Communications and Technology*. New York, NY: Springer, pp. 77–87.

Brinkmann S (2014) Unstructured and Semi-Structured Interviewing. In: Leavy P (ed.) *The Oxford Handbook of Qualitative Research*. Oxford University Press, pp. 277–299.

Clark R (2014) Cognitive Task Analysis for Expert-Based Instruction in Healthcare. In: Spector JM, Merrill MD, Elen J, et al. (eds) *Handbook of Research on Educational Communications and Technology*. New York, NY: Springer, pp. 541–551.

Crichton MT (2017) From cockpit to operating theatre to drilling rig floor: five principles for improving safety using simulator-based exercises to enhance team cognition. *Cognition, Technology & Work* 19(1): 73–84.

Dahlstrom N, Dekker S, van Winsen R, et al. (2009) Fidelity and validity of simulator training. *Theoretical Issues in Ergonomics Science* 10(4). Taylor & Francis: 305–314.

Frerejean J, van Merriënboer JJG, Condron C, et al. (2023) Critical design choices in healthcare simulation education: a 4C/ID perspective on design that leads to transfer. *Advances in Simulation* 8(1): 5.

Gyldensten WC, Wiig AC and Sellberg C (2023) Maritime Students' Use and Perspectives of Cloud-Based Desktop Simulators: CSCL and Implications for Educational Design. *TransNav* 17(2): 315–321.

Hontvedt M (2015) Professional vision in simulated environments — Examining professional maritime pilots' performance of work tasks in a full-mission ship simulator. *Learning, Culture and Social Interaction* 7: 71–84.

Hontvedt M and Øvergård KI (2020) Simulations at Work — a Framework for Configuring Simulation Fidelity with Training Objectives. *Computer Supported Cooperative Work (CSCW)* 29(1–2): 85–113.

Hoogveld AWM, Paas F, Jochems WMG, et al. (2002) Exploring teachers' instructional design practices from a systems design perspective. *Instructional Science* 30(4). Springer: 291–305.

Hoogveld AWM, Paas F and Jochems WMG (2005) Training higher education teachers for instructional design of competency-based education: Product-oriented versus process-oriented worked examples. *Teaching and Teacher Education* 21(3): 287–297.

Kandemir I and Cicek K (2023) Development an instructional design model selection approach for maritime education and training using fuzzy axiomatic design. *Education and Information Technologies* (28): 11291–11312.

Kim T, Sharma A, Bustgaard M, et al. (2021) The continuum of simulator-based maritime training and education. *WMU Journal of Maritime Affairs* 20(2): 135–150.

Kirschner P and van Merriënboer JJG (2008) Ten Steps to Complex Learning: A New Approach to Instruction and Instructional Design. In: *21st Century Education: A Reference Handbook*. 2455 Teller Road, Thousand Oaks California 91320 United States: SAGE Publications, Inc., p. I-244-I–253.

Manuel ME (2017) Vocational and academic approaches to maritime education and training (MET): Trends, challenges and opportunities. *WMU Journal of Maritime Affairs* 16(3): 473–483.

Mullet HG, Butler AC, von Borries R, et al. (2014) Delaying feedback promotes transfer of knowledge despite student preferences to receive feedback immediately. *Journal of Applied Research in Memory and Cognition* 3(3): 222–229.

Nause N, John P and Klimmek E (2017) International maritime management: A distance-education M. Sc. course for nautical officers onboard sea-going ships. In: *18th Annual General Assembly of the International Association of Maritime Universities - Global Perspectives in MET: Towards Sustainable, Green and Integrated Maritime Transport*, Varna, Bulgaria, 2017, pp. 54–63.

Nikitakos N, Sirris I, Dalaklis D, et al. (2017) Game-based learning for maritime education and training: The case of Trader of the World. *WMU Journal of Maritime Affairs* 16(2): 265–291.

Patil M, Balaji R and Shikhare R (2022) Smarter Education Methodologies for MET: An approach with Augmented Reality. In: *OCEANS 2022 - Chennai*, February 2022, pp. 1–8.

Reigeluth CM (1999) The elaboration theory: Guidance for scope and sequence decisions. In: *Instructional-Design Theories and Models: A New Paradigm of Instructional Theory, Vol. II*. Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers, pp. 425–453.

Sellberg C (2018) From briefing, through scenario, to debriefing: the maritime instructor's work during simulator-based training. *Cognition, Technology & Work* 20(1): 49–62.

Sellberg C, Lindmark O and Rystedt H (2018) Learning to navigate: the centrality of instructions and assessments for developing students' professional competencies in simulator-based training. *WMU Journal of Maritime Affairs* 17(2): 249–265.

Sellberg C, Lindwall O and Rystedt H (2021) The demonstration of reflection-in-action in maritime training. *Reflective Practice* 22(3): 319–330.

Shankar M and Balaji R (2022) IMO Session in Classroom: A Case in Experiential Learning. In: *Proceedings of the International Association of Maritime Universities Conference 2022*, Batumi, Georgia, 2022, pp. 293–301.

Szwed P and Rooks M (2014) Maritime International Exchange (MIX): Designing blended, application-focused exchange programs to increase cross-cultural learning. In: *15th Annual General Assembly International Association of Maritime Universities, IAMU AGA 2014 - Looking Ahead: Innovation in Maritime Education, Training and Research*, Launceston, Australia, 2014, pp. 394–404.

Tjiam IM, Schout BMA, Hendrikx AJM, et al. (2012) Designing simulator-based training: An approach integrating cognitive task analysis and four-component instructional design. *Medical Teacher* 34(10). Taylor & Francis: e698–e707.

van Merriënboer JJG, Jelsma O and Paas FGWC (1992) Training for reflective expertise: A four-component instructional design model for complex cognitive skills. *Educational Technology Research and Development* 40(2): 23–43.

van Merriënboer JJG, Kester L and Paas F (2006) Teaching complex rather than simple tasks: Balancing intrinsic and germane load to enhance transfer of learning. *Applied Cognitive Psychology* 20(3): 343–352.

van Merriënboer JJG van and Kirschner PA (2017) *Ten Steps to Complex Learning: A Systematic Approach to Four-Component Instructional Design*. 3rd ed. New York: Routledge.