An Experimental Study to Explore the Effectiveness of a 3D Maritime Serious Game Prototype: Maritime Leaders at Sea

Suleyman Cihan Gurbuz[1], Metin Celik[2]

This paper conducts a comprehensive experimental study designed to investigate the effectiveness of a maritime serious game called Maritime Leaders at Sea (ML@S). The 3D cutting-edge prototype targets to enhance leadership and teamwork skills of undergraduate maritime students via engaging them in immersive gameplay scenarios reflective of real-world challenges at sea. Competing the ML@S sessions, the number of 76 students were included in the feedback assessment survey to assess their perceptions and attitudes on the simulated environment. The feedback is also linked to the learning analytics perspective to involve time and scoring data of players through different levels at operational scenarios. Preliminary analyses reveal promising results, suggesting a positive correlation between participation in ML@S, feedbacks after sessions, and improvements in leadership and teamwork as key competencies. It is anticipated that this study will make significant contributions towards game developers, technology start-ups, educational institutions, and global shipping companies. The implications of the study offer valuable insights for the development of future serious games aimed at enhancing essential skills of maritime human resources in dynamic and high-stakes environments.

KEY WORDS

~ Serious games
~ Maritime competencies
~ Leadership and teamwork
~ Maritime human resources
~ Educational games

[1] Istanbul Technical University, Department of Marine Transportation Engineering, Istanbul, Türqiye
[2] Istanbul Technical University, Department of Basic Science, Istanbul, Türqiye
e-mail: gurbuz18@itu.edu.tr
doi: 10.7225/toms.v13.n02.019

Received 21 Mar 2024 / Revised on: 12 Jul 2024 / Accepted: 30 Aug 2024 / Published: 21 Oct 2024

1. INTRODUCTION

About two million seafarers are contributing to the transportation of around 90 percent of the world's trading products (ICS, 2020). The literature reveals that human error still is the primary cause for the majority of ship accidents (Luo & Shin, 2019; Akyuz & Celik, 2018). In fact, lack of skills, training, and experience are the main reason of human error on ships (Paolo et al., 2021). This being the case, well-trained and competent seafarers are of significant importance for safe and efficient operation of shipping, as well as protection of the maritime environment.

Seafarers need to function together as a team for most of the shipping operations, such as safe navigation, cargo handling, repairing and maintenance, maintaining physical security, etc. For this reason, serving onboard ships requires both soft skills and technical (hard) skills. Maritime technical skills are practical skills which include theoretical knowledge and the competency to apply this knowledge (Mallam et al., 2019), while soft skills can be defined as the ability to interact successfully with the environment, facilitating the application of technical skills in the real world (Rao, 2014). Competencies in soft skills need to be paid more attention to in MET for ensuring safety and efficiency of shipping operations (Sellberg et al., 2019).

International Convention on Standards of Training, Certification and Watchkeeping (STCW) 1978, as amended in 2010 (referred as STCW in this study), issued by International Maritime Organisation (IMO), defines minimum competency standards of seafarers. However, there is an important gap between the required on-board competency level of seafarers and their actual level of competency. This gap partly originates from the theoretical nature of MET and the lack of practical training in maritime institutions (ICS, 2020).

For providing maritime students with enhanced practical training, maritime industry needs to find cheaper, easier, and more flexible ways of training. Game-based learning, as a technology-enabled instructional method, offers a great potential for the maritime domain (Nikitakos et al., 2017). Serious games can enhance MET practices in maritime institutions by providing active learning environments for practical competency development, anytime and regardless of the physical location of the students (Bruzzone et al., 2013).

With this perspective, the current study aims to provide insight into design and utilisation of maritime serious games. For doing this, application of a 3D maritime serious game prototype, namely "Maritime Leaders at Sea (ML@S)", has been conducted with 76 undergraduate maritime students. Based on the perception and attitude of the students, as well as comprehensive statistical analysis, important results that might potentially provide key insight into maritime serious gaming have been achieved.

The rest of the study is structured as follows: Serious game literature review, research objectives and research questions are proposed in Section 2. Methodology of the study is explained in Section 3, while Section 4 presents the results. A discussion about theoretical implications of the study and utilisation of serious games in maritime domain is provided in Section 5. Finally, the study is concluded in Section 6, which provides a short summary on interpretation of the results, as well as future research directions and limitations of the study.

2. THEORETICAL BACKGROUND

2.1. Serious Games

The term "Serious Game" was first used in 1968 when Clark Abt examined war-games and simulations and defined them as "having an explicit and carefully thought-out educational purpose and not intended to be played primarily for amusement. This does not mean that serious games are not or should not be entertaining." (Abt, 1970, p. 9). Serious games are also defined as games which are developed for educational purposes and engage players in significant learning experience (Djaouti et al., 2011).

The literature reveals that game elements improve the learning efficiency in different ways. Firstly, it is stated that game elements increase engagement and motivation and thus promote higher-order learning (Gray et al., 2019; Zainuddin et al., 2020; Ranieri et al., 2021). In addition, Bai et al. (2020) state that game elements, such as points, challenges, badges, and gaming goals improve learning outcomes by increasing participation in learning. Serious games can also be successful in teaching knowledge, as well as optimising intrinsic motivation and cognitive load (Ye et al., 2022). In addition, serious games develop understanding and retention (Wang & Abbas, 2018), empower critical thinking (Haruna et al., 2021; Turner et al., 2018), and promote attitude change (Chow et al., 2020), while fostering goal setting (Yıldırım & Şen, 2019).

Gamification uses game mechanisms and elements for non-game related purposes (Zimmerling et al, 2019). Gamification approach is commonly adopted as it improves traditional educational methods (Swacha, 2021). To start with, gamification of traditional online learning experiences enhances motivation and engagement of students in a way to help them focus better on the course contents. In comparison with the traditional learning methods, gamification also provides students with a better insight into their achieved learning level and helps them to remain connected with the target level of the overall learning process (Kaufmann, 2018). Marín et al. (2019) explain that gamification facilitates increased and long-term learning of programming language in comparison with traditional learning methods. They further state that gamification of traditional learning increases interactions between students, thereby providing active learning experiences.

Serious gaming applications have been gaining popularity in different fields. To start with, they are commonly utilised for providing healthcare personnel and students with authentic training experience in a risk-free environment (Haruna et al., 2019; Sardi et al., 2017; Teschner, 2016). Serious games are also widely employed in education (Wronowski et al., 2020; Zhao & Shute, 2019; Calvo-Morata et al., 2019). Increasing bullying awareness (Alonso-Fernandez et al., 2023), business (Fu et al., 2016; Fotiadis & Sigala, 2015), music (Margoudi et al., 2016), promoting leadership skills (Buzady et al., 2022), language learning (Alyaz et al., 2017), are among other fields where serious games are used. If you are using graphs as figures, please do so in xls/xlsx format (excel or similar graph embedded in this template). Low resolution graphs and charts saved as raster image (gif, jpeg, png) imported copy/pasted into template are not acceptable.

Integration of immersive technologies, such as Augmented Reality (AR) and Virtual Reality (VR), with gamification and serious games enhances the effectiveness of game-based learning in different ways. To start with, AR and VR technologies enable interactive and realistic learning experiences (Pellas et al, 2019). AR and VR technologies also support the 3D visualisation of abstract concepts, such as solar systems which are difficult or impossible to observe using traditional educational methods (Yeh and Tseng, 2020). Akçayır and Akçayır (2017) also concluded that AR approach might improve learning motivation and foster collaboration and interaction among students. In this regard, utilisation of AR/VR-based serious games is common in foreign language learning (Lee, 2022; Lee and Park, 2019), computing education (Petri and von Wangenheim, 2017), healthcare education and training (Chang et al, 2022; Mohamad et al., 2021; Plotzky et al, 2021) military and sports training (Ahir et al, 2020), as well as maritime education and training (Chae et al, 2021; Michailidis et al, 2020; Weng and Li, 2019; Bandara et al, 2020).

2.2. Evaluation of the Serious Games

Effectiveness of serious games has been evaluated using different approaches. The traditional methodology utilises paired questionaries before and after the game to assess players and then compare the results in order to evaluate the serious game (Calderón & Ruiz, 2015). Pre-test and post-test experimental research designs are also commonly used instead of or together with questionnaires for the same purpose (Bai et al., 2020; Fiellin et al., 2017; Haruna et al., 2019).

Evidence-based internal evaluation approaches have lately been more commonly used instead of the afore mentioned external measures. Learning analytics, which is defined as measurement, collection, and analysis of educational data for the purpose of understanding and enhancing the learning experience (Long et al., 2011), has arisen as a new approach for evidence-based evaluation of serious games. For instance, Udeozor et al. (2022) used learning analytics approach for serious game evaluation and enhancing training effectiveness. Cano et al. (2018) also utilised learning analytics approach for validating a serious game for training skills in transportation. In addition, Alonso-Fernández et al. (2023) offered combining traditional pre-post experiments method, Game Learning Analytics approach, and data mining method for evidence-based serious games evaluation.

Looking critically at serious game evaluation literature, it may be concluded that more studies explaining standard procedures for combining traditional measures, such as questionnaires with more dynamic gameplay data, are needed (Liu et al., 2017). In fact, maritime serious gaming literature lacks experimental studies utilising both traditional (pre/post survey) and evidence based (learning analytics) methods. This study aims at filling this research gap by providing a perspective on evaluating maritime serious games, using a combination of traditional and evidence-based method in a way to shed light on their effective design and utilisation in the maritime domain.

2.3. Maritime Serious Games

Serious gaming has been gaining popularity in maritime literature in the last decade. Researchers proposed serious games for education and training of seafarers, as well as maritime students, on STCW-based competencies. To start with, Gurbuz and Celik (2022) provided a step-by-step approach to the preliminary design, development and prototyping of "Maritime Risk Assessment at Sea (MRA@S)" game. The game which is conceptualised as the first module of the "Maritime Gamentor" platform aims to train the crew on task-based risk assessment about the enclosed space entry operations onboard tanker ships. In addition, Nikitakos et al. (2017) proposed alpha version of the "Trader of the World" game for navigational safety training of seafarers and maritime students and reported receiving satisfactory feedback from undergraduate students.

With regard to STCW-based competencies, Bruzzone et al. (2013) also created a serious game for familiarisation of the crew with operating procedures onboard ships. In addition, Sartini (2020) put forward that serious gaming approach enhanced maritime English-speaking skills of cadets. Lastly, Türkistanlı and Kuleyin (2022) designed and applied a serious game for enhancing decision-making skills of maritime students in collision prevention situations. Applying traditional pre-test/post-test experimental design for evaluation of the game, they found that the game-based training supported students in developing their decision-making skills. In fact, it has been discovered that their study is one of the few studies in maritime literature evaluating the effectiveness of a serious game. In this regard, it has been concluded that the maritime literature needs comprehensive studies providing methods of serious game evaluation.

2.4. Research Objective and Contribution

Critical analysis of the literature reveals that there are some significant research gaps in maritime serious gaming literature. To start with, there is a need for fundamental studies which would provide practical guidance on design and development of maritime serious games. The existing studies, although providing maritime serious games, fail to practically guide future maritime serious game design and development efforts as they do not provide a specific design model or explanation regarding the procedure they follow during the design and development process.

Secondly, experimental studies thoroughly analysing the experiences and perceptions of maritime students on maritime serious games are also limited. Most of the existing experimental studies use a traditional pre/post survey approach and fail to provide a comprehensive insight into design, development, and utilisation of maritime serious games. It is believed that a detailed experimental study of maritime serious games is needed not only for enhancing their effectiveness but also for shedding light on their effective utilisation within the MET practices.

For filling the research gap regarding experimental studies, the current study proposes a methodology for evaluating maritime serious games using both traditional (pre/post survey) and evidence based (learning analytics) methods. More specifically, this study collects data both from surveying students and from their gameplay interaction, such as game time and game score, and analyse statistical relationship between them in order to answer research questions, as explained in Chapter 4.2. For instance, Research Question-2 analyses statistical relationship between previous gaming habit, collected by pre-survey, and ML@S total game time which is recorded during gameplay experiences taking learning analytics perspective.

In broader perspective, the objective of this research is providing insight and guidance into the design and utilisation of maritime serious games by conducting a comprehensive experimental study. We would like to further emphasise that the research objective is closely rooted in the literature review regarding the evaluation of the serious games. As well as providing practical contribution to maritime competency development, it is thus believed that this study has the potential to contribute towards filling the existing gaps in maritime serious gaming literature.

3. METHODOLOGY

3.1. Procedure and Participants

In this study, seventy-six (76) undergraduate maritime students have played the ML@S game. After that, the students answered a 27-question survey regarding their experiences and perceptions about the game. All the students were informed about the experimental design and their role in it.

The experimental study was conducted remotely in three online sessions as the classes were being held online during the time of the study. Eighty-six (86) undergraduate maritime students attended the online sessions and 76 (88 %) of them actually completed the study. Thirty (30), thirty-six (36), and ten (10) students completed the study in the first, second, and third sessions respectively. The sessions lasted about two hours. In the first thirty minutes of the sessions, the students were familiarised with the overall study and the ML@S game. Then the students downloaded and played the game for about one hour. In the final thirty minutes of the sessions, the students answered the survey about their perceptions of the game.

All the participants were deck students from İstanbul Technical University Maritime Transportation Engineering programme. Seventy (92%) of the students were male and six (8%) of them were female. Twenty (26%) of the students were from the 1st class, forty-five (59%) of them were from 2nd class, five (7%) of them were from the 3rd class, and six (8%) from the 4th class of the school. Forty (53%) of these students reported having taken theoretical leadership education at school before. In addition, forty-four (58%) students reported playing at least one serious game, while six (8%) students reported having played a maritime serious game before.

Information about the students' previous gaming habits and perception of playing computer games have also been collected. In this regard, eight (10.5%), seventeen (22%), eighteen (24%), fifteen (20%), eight (10.5%), ten (13%) students have reported playing computer games less than one hour, one to four hours, five to ten hours, eleven to fifteen hours, sixteen to twenty hours, and more than twenty hours a week respectively. Besides, twenty (33%) students have reported that they certainly enjoy playing computer games, while two (3%3) of them have declared that they certainly do not enjoy it. Collected information about previous gaming habits and perception of playing computer games is depicted in Table 1 and Table 2 respectively.

≤ 1h	1 to 4	5 to 10	11 to 15	16 to 20	>20 h
8 (%10.5)	17 (%22)	18 (%24)	15 (%20)	8 (%10.5)	10 (%13)

Table 1. Previous gaming habits of the students (hours in a week)

Certainly disagree	**Disagree**	**Slightly disagree**	**Slightly agree**	**Agree**	**Certainly agree**
2 (%3)	4 (%5)	5 (%7)	14 (%18)	26 (%34)	25 (%33)

Table 2. Gaming perception of the students (I enjoy playing computer games)

Using the explained procedure, an experimental study to assess and validate the ML@S game by investigating the maritime students' perceptions and attitude has been conducted. In this regard, sixteen research questions are intended to be answered (in Chapter-4) for providing insight into design, development, and utilisation of maritime serious games. The research questions deal with the statistical relationship between previous gaming habit, previous gaming perception, previous theoretical maritime education, as well as motivation and engagement of the players with gameplay success, gameplay motivation, gaming time, and intention concerning a future use of similar games.

3.2. Maritime Leaders at Sea (ML@S) Game

ML@S is a 3D maritime serious game intended to enhance the leadership and teamwork skills of young seafarers and undergraduate maritime students. The game was designed using Serious Game Design for Maritime (SGDM) model as proposed by Gurbuz (2021). SGDM is explained to be the first serious game design model which is specific to the maritime domain. The model proposes eight steps in designing a maritime serious game from the beginning to the end (Gurbuz, 2021). The game was then prototyped using Unity3D® game engine (Version: 2019.4.12f1) for Windows® and Mac® platforms.

In the game, the player is the master of a merchant ship M/V Maritime Leaders-1. The master is on the bridge, where a navigational watch is kept. On the navigational watch, 3rd Officer, who has just one year of seagoing experience, is serving as officer of the watch. The lookout and the helmsman are also on the watch. The duty of lookout is maintaining a continuous state of alert by sight and hearing against dangers to navigation. Also, the helmsman is responsible for timely and correct application of rudder orders that the officer in charge or the captain gives. Additionally, it is assumed throughout the game that there is no malfunction or failure in any system onboard the ship. Outside view of the M/V Maritime Leaders-1 ship and a navigational watch on the bridge of the ship are depicted in Figure 1 and Figure 2 respectively.

Figure 1. Outside view of M/V Maritime Leaders-1 ship

Figure 2. 3rd Officer and Helmsman during a navigational watch on the bridge

The game has three levels. In Level-1, there are four theoretical questions. In Level-2, the player is involved in five short scenarios of a navigational watch on the bridge. The reactions of the player to his/her teammates will affect their physical and/or mental conditions and thus their behaviours in Level-3, which is the main and the most challenging level of the game. In Level-3, the player is on a navigational watch sailing in Marmara Sea towards the entrance of Istanbul Strait from South. There is dense fog, which limits the visibility. Throughout the level, the player, as the master, will be involved in some cases where s/he needs to use leadership skills. Later in the level, M/V Maritime Leaders-1 will be involved in a risky situation with another ship and try to avoid collision.

The player starts the game with 100 points and loses points for each incorrect answer/reaction, which costs 1 point in Level-1, 2 points in Level-2, and 5 points in Level-3. The player gets a feedback after each answer. More comprehensive and knowledge-building feedback is presented after wrong answers (compared to correct answers), so that the player can develop the necessary skills by learning from his/her mistakes. The player needs to both avoid collision and score higher than 70 points to be successful in the game and will fail in case of a collision regardless of the score. The player has two minutes for answering each theoretical question in Level-1 and 45 seconds for his/her reactions in Level-2 and Level-3. If not provided within these time limits, answers/reactions are assumed incorrect. An example of a challenge in the scenario and associated feedback for the wrong reaction are shown in Figure 3 and Figure 4 respectively.

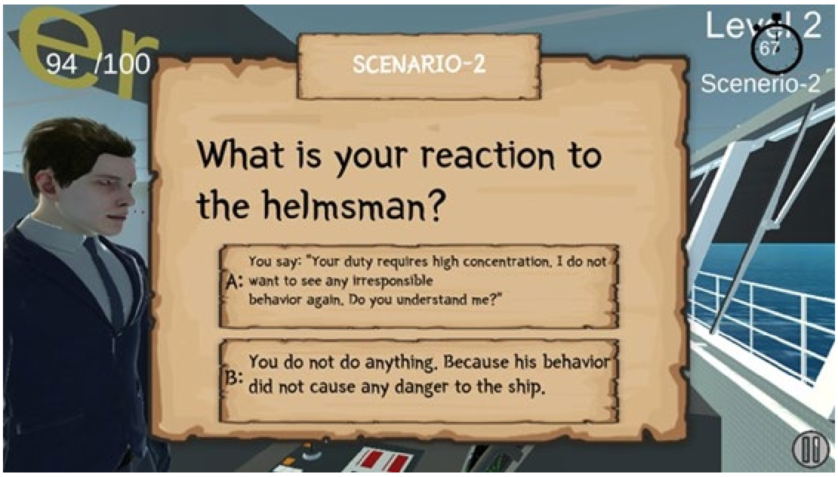

Figure 3. Challenge of the Level-2 Scenario-2

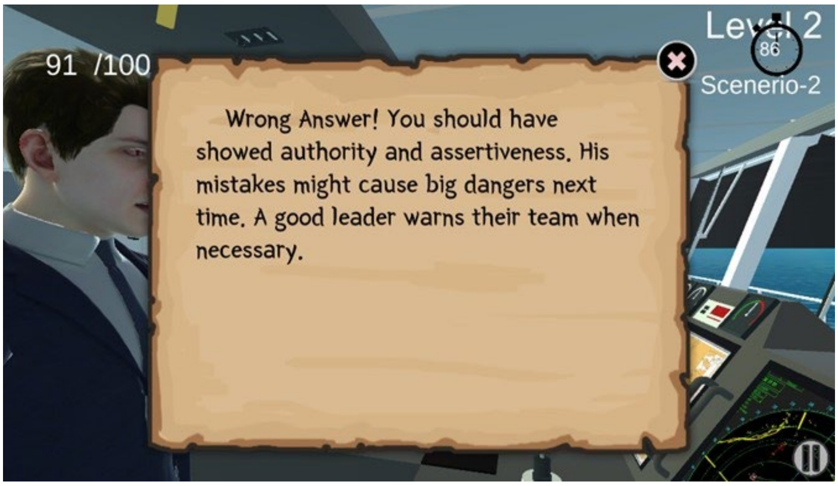

Figure 4. Feedback for the challenge in Figure-3

3.3. Data Collection

3.3.1. The Survey

After the students have played the ML@S game, a survey has been applied to measure their experiences and perceptions concerning the game. The survey includes twenty-seven (27) questions forwarded to the students through e-mail. The questions have required close-ended answers on a 6-point Likert Scale with 1 being “Certainly Disagree”, 2 “Slightly Disagree”, 3 “Disagree”, 4 “Slightly Agree”, 5 “Agree”, and 6 being “Certainly Agree”.

For creating survey questions, the literature has been reviewed with a focus on measuring technology acceptance of students. Based on Technology Acceptance Model (TAM) by Davis (1985) and the Unified Theory of Use and Acceptance of Technology (UTAUT) by Venkatesh et al. (2003), it was concluded that ‘perceived ease of use’ and ‘perceived usefulness’ are important factors that affect intentions of students on playing educational games (Bourgonjon et al., 2010; Fagan et al., 2012). Perceived ease of use is “the degree to which an individual believes that using a particular system would be free from physical and mental effort, while perceived usefulness can be defined as the degree to which a person believes that using a particular technology will enhance his or her job performance (Davis, 1993).

In addition, “motivation and engagement” is stated as being one of the most important factors on students’ acceptance of serious games (Beavis et al., 2015;). Measuring the future intentions of students on playing ML@S or similar games is another purpose of the survey. In this regard, the questions were created under four categories, which are; “Motivation and Engagement”, “Perceived Usefulness”, “Perceived Ease of Use”, and “Intention on Future Use”. The survey questions are included in Appendix-1.

3.3.2. Gameplay Data

This study also utilises learning analytics perspective for making more detailed analysis of students’ learning experience. In this regard, some gameplay data is recorded to be used in the statistical analysis and thus better understanding the students’ learning experience with ML@S game. The data is automatically recorded to the game server for each student through adding the necessary coding lines in C# language. The gameplay data recorded is shown in Table 3.

Number	Recorded Data
1.	Game Score
2.	Lost Points in Each Level
3.	Total Game Time
4.	Total Time on Tasks (Questions)
5.	Total Time on the Scenarios
6.	Time on Questions in Each Level
7.	Time on Scenarios in Each Level

Table 3. Recorded gameplay data

All of the data recorded has been used in the analysis. To start with, game score and lost points in each level data are used as a representative of gameplay success of the students for the whole game and each level respectively. Time on the scenarios data is considered as a sign of gameplay engagement. Possible relationship of the time students spent on questions and perceived ease of use has also been analysed to gain insight into behaviours of students when they experience difficulty in the game. It is assumed for the purpose of this study that the time students spend in the game (both on the questions and on the scenario) is a good representative of their gameplay experience and can be used for acquiring results on their gaming perceptions.

3.4. Data Testing

The survey and gameplay data are then analysed using IBM SPSS ® Version 28. Data analysis includes normality test, and sampling adequacy analysis, as well as validity and reliability tests.

3.4.1. Normality Testing

The survey and gameplay data is firstly tested for normality. A normal distribution means that there is neither skewness nor kurtosis. The survey and gameplay data in our study can be regarded as normally distributed since the skewness and kurtosis of the data fall within the range of -3 to 3 (Farrell & Rogers-Stewart, 2006).

3.4.2. Sampling Adequacy Testing

Kaiser-Meyer-Olkin (KMO) and Bartlett tests have been performed to analyse the sampling adequacy. KMO test explores if the sampling size is suitable for factor analysis and the KMO value must be above 0.6 for an adequate sampling size (Tabachnick et al., 2013). KMO test result of 0.854 in our study confirms that the collected data was adequate for factor analysis. The Bartlett Sphericity test result of $p=0.000$ ($p<0.5$) has also validated the correlation within the collected data and confirmed that factor analysis can be applied to it.

3.4.3. Validity Testing

Validity explains if an instrument correctly measures what it is supposed to measure (Sekaran & Bougie, 2010). In this study, validity of the dataset has been tested through examining convergent validity. Convergent validity explains if the items measuring the same construct are correlated (Hair et al., 2014).

For examining convergent validity, factor loadings have been firstly calculated through factor analysis. The calculated factor loadings are included in Table 4. Factor loadings are positively correlated with the contribution each item (question) has to what it intends to measure. The loadings should be 0.4 or above, meaning that each measure explains 40% or more of the variance and can be assumed reliable (Sekaran & Bougie, 2010). As this is the case in our study, we have concluded that our data has convergent validity.

Question	Factor Loading	Question	Factor Loading
1.	0,549	**15.**	0,853
2.	0,673	**16.**	0,848
3.	0,486	**17.**	0,702
4.	0,593	**18.**	0,803
5.	0,687	**19.**	0,594
6.	0,667	**20.**	0,415
7.	0,582	**21.**	0,669
8.	0,576	**22.**	0,773
9.	0,485	**23.**	0,816
10.	0,723	**24.**	0,882
11.	0,618	**25.**	0,866
12.	0,751	**26.**	0,783
13.	0,781	**27.**	0,754
14.	0,774		

Table 4. Factor loading values for the survey questions.

3.4.4. Reliability Testing

Reliability measures how consistently a test measures a construct. For testing the reliability, Cronbach's Alpha values, which measure the internal consistency of the items, have been calculated at 95% Confidence Level and depicted in Table 5. The Cronbach's Alpha values for each category of items and the overall survey are between 0.862 and 0.947, which can be considered acceptable as they are above the threshold level of 0.7 (Hair et al., 2014).

Question Type	Cronbach Alpha Value
Motivation and Engagement	0,872
Motivation and Engagement	0,903
Perceived Ease of Use	0,862
Intention in Future Use	0,887
Overall Survey	0,947

Table 5. Cronbach Alpha values for survey questions

4. RESULTS

This section presents the results of the descriptive analysis and statistical analysis conducted for answering the Research Questions.

4.1. Descriptive Analysis

The analysis in this section provides a short summary of the research variables applied to create a clear picture of the survey and gameplay data.

To start with, the average game score of the students is 86,75, the minimum score being 72, the maximum score being 100. As the required score is 70 to win the game, the success rate in the game is 100 %. The students have finished the game in 789.80 seconds (approximately in 13.5 minutes) on average. In fact, the average time encountered is lower than anticipated before the experimental study. The total game time of the students has varied within 320 and 1289 seconds. The descriptive statistics of the game score and total game time are summarised in Table 6 below.

	Mean	Median	Standard Deviation	Min-Max	Success Rate (%)
Game Score	86,75	86	6,75	72-100	100
Total Game Time (sec.)	7898,80	808,5	182,49	320-1289	N/A

Table 6. The descriptive statistics of game score and total game time

Looking at the student answers in the survey, we may conclude that they mostly have positive perception of the game. 61.3 % of the students have stated that they either agree or certainly agree to have motivation and engagement in the game. The average of students' answers to this group of questions is 4.68, which is between slightly agree and agree. Besides, 65.2 % of the students have perceived (agreed or completely agreed) the game as useful for their leadership skills.

The average of the answers to the perceived usefulness questions is 4.81, which is between slightly agree and agree, coming closer to agree. In terms of ease of use, 70 % of the students agreed or certainly agreed that the game was easy for them to understand, control, and also succeed. The average answer in this group is 4.94, which is close to agree. Moreover, 77 % of the students have stated that they are willing to use similar serious game in the future for educational purposes. The average of the answers as regards future intention is 5.00, which means agree in the scale.

4.2. Research Questions

This section presents the results for sixteen (16) research questions of the study for providing insight into design and utilisation of maritime serious games.

4.2.1. Research Question-1

Is there a statistically significant relationship between previous gaming habits (gaming hours in a week) and ML@S game success of the students?

One way Anova test (F=8,289, p=0,000) has shown that there is a statistically significant relationship between gaming habits and game success (score) of the students at 95 % confidence level. In addition, Scheffe Test reveals that the students who play computer game between 16-20 hours a week score statistically higher than the ones who play less than 1 hour, 1-4 hours, and 5-10 hours.

4.2.2. Research Question-2

Is there a statistically significant relationship between previous gaming habits (gaming hours in a week) and ML@S total game time of the students?

One way Anova test (F=2,596, p=0,033) has shown that there is a statistically significant relationship between previous gaming habits and total time the players spend in the game. Besides, Bonferroni Test revealed that the students who played computer game between 5-10h a week (709,89) spent statistically less time in the game than the ones who play between 16-20h (953, 75).

4.2.3. Research Question-3

Is there a statistically significant relationship between previous gaming perception (enjoyment of the game) and ML@S game success of the students?

Pearson Correlation Coefficient test has defined at 95 % confidence level that (r=0,299, p=0,009) there is a statistically positive but almost weak (r<0,3) (Cohen, 1988) relationship between gaming perception and game success of the students.

4.2.4. Research Question-4

Is there a statistically significant relationship between previous gaming perception (enjoyment of the game) and ML@S total game time of the students?

Pearson Correlation Coefficient test (r=0,005, p=0,964) shows at 95 % confidence level that there is no statistically significant relationship between gaming perception and total game time of the students.

4.2.5. Research Question-5

Do the students who have previously taken leadership education at school score statistically higher than the students who have not taken this education?

Independent sample t test (t=2,196, p=0,031) has proved at 95 % confidence level that the students who have taken leadership education before (88,33) score statistically higher (85,00) than the ones who have not taken such an education before.

4.2.6. Research Question-6

Do the students who have previously taken leadership education at school spend statistically more time in the game scenarios than the students who have not taken such education?

Independent sample t test result between taking leadership education before and time spent in scenarios in each level is shown below:

Level-1: (t=1,809, p=0,074, p<0,05)	No relationship
Level-2: (t=1,861, p=0,067, p<0,05)	No relationship
Level-3: (t=2,667, p=0,009, p<0,05)	Yes

The test reveals at 95 % confidence level that the students who have taken leadership education before (404,25) spend more time (341,17) in Level-3 (but not in Level-1 and Level-2) than the ones who have not taken leadership education.

4.2.7. Research Question-7

Do the students who have previously taken leadership education at school exhibit statistically higher motivation and game effectiveness than the students who have not taken such education?

Independent sample t test result between taking leadership education before and perceived motivation and game effectiveness is presented below:

Motivation: (t=-0,16, p=0,873, p<0,05)	No relationship
Game Effectiveness: (t=1,861, p=0,067, p<0,05)	No relationship

The test shows at 95 % confidence level that there is no statistically significant relationship between previous leadership education and their perceived motivation and game effectiveness.

4.2.8. Research Question-8

Is there a statistically significant relationship between the gameplay success and the time spent in the scenarios on each level?

Pearson Correlation Coefficient test result for the time spent and game scores in each level is explained below:

Level-1: (r=-0,340, p=0,003, p<0,05).	Yes, medium strength relationship (0,3<r<0,5)
Level-2: (r=-0,365, p=0,001, p<0,05).	Yes, medium strength relationship (0,3<r<0,5)
Level-3: (r=-0,420, p=0,000, p<0,05).	Yes, medium strength relationship (0,3<r<0,5)

The test has proved at 95 % confidence level that the time spent in the scenarios and the gameplay success have statistically significant relationship at medium strength (Cohen, 1988).

4.2.9. Research Question-9

Is there a statistically significant relationship between the gameplay success and the time spent on tasks (for answering the questions) on each level?

Pearson Correlation Coefficient test results for the relationship between time spent answering the questions and game scores for each level are presented below:

Level-1: ($r=-0,324$, $p=0,004$, $p<0,05$)	Yes, medium strength relationship ($0,3<r<0,5$)
Level-2: ($r=-0,236$, $p=0,040$, $p<0,05$)	Yes, weak relationship ($r<0,3$)
Level-3: ($r=-0,111$, $p=0,341$, $p<0,05$)	No relationship

The test has proved at 95 % confidence level that the time spent for answering the questions and the gameplay success have medium strength and weak (Cohen, 1988) correlation in Level-1 and Level-2 respectively, but no correlation in Level-3.

4.2.10. Research Question-10

Is there a statistically significant relationship between the total time spent on tasks (for answering the questions) and the perceived difficulty of the game?

Pearson Correlation Coefficient test results are explained below:

Level-1: ($r=0,125$, $p=0,283$, $p<0,05$).	No relationship
Level-2: ($r=0,042$, $p=0,716$, $p<0,05$).	No relationship
Level-2: ($r=0,042$, $p=0,716$, $p<0,05$).	No relationship

The test illustrates that at 95 % confidence level there is no statistically significant relationship between difficulty perception of the students and the time they spend on answering the questions.

4.2.11. Research Question-11

Is there a statistically significant relationship between the gameplay success of the students and their perceived motivation and engagement?

Pearson Correlation Coefficient test ($r=0,125$, $p=0,283$, $p<0,05$) depicts that at 95 % confidence level there is not a statistically significant relationship between perceived motivation of the students and their gameplay success.

4.2.12. Research Question-12

Is there a statistically significant relationship between the gameplay success of the students and their intention concerning future use of serious games?

Pearson Correlation Coefficient test ($r=0,199$, $p=0,085$, $p<0,05$) shows that at 95 % confidence level that a statistically significant relationship between students' intention concerning future use of similar serious games and their gameplay success does not exist.

4.2.13. Research Question-13

Is there a statistically significant relationship between the perceived motivation and engagement of the students and their intention concerning future use of serious games?

Pearson Correlation Coefficient test (r=0,564, p=0,000, p<0,05) illustrates that at 95 % confidence level there is a statistically significant and strong relationship (0,5<r) (Cohen, 1988) between motivation and engagement of the students' and their intention concerning future use of similar serious games.

4.2.14. Research Question-14

Is there a statistically significant relationship between the perceived motivation and perceived game effectiveness?

Pearson Correlation Coefficient test (r=0,823, p=0,000, p<0,05) has proved that at 95 % confidence level there is a statistically significant and strong (r>0,5) (Cohen, 1988) relationship between perceived motivation and engagement and perceived game effectiveness of the students.

4.2.15. Research Question-15

Is there a statistically significant relationship between previous gaming perception of the students and their motivation and engagement in the ML@S game?

Pearson Correlation Coefficient test (r=0,365, p=0,001, p<0,05) has shown that at 95 % confidence level there is a statistically significant and medium strength (0.5>r>0,3) (Cohen, 1988) relationship between previous gaming perception of the students and their motivation and engagement in the ML@S game.

4.2.16. Research Question-16

Is there a statistically significant relationship between the motivation and engagement of the students and the total time they spend in the game?

Pearson Correlation Coefficient test (r=0,234, p=0,042, p<0,05) shows that motivation and engagement of the students has statistically significant but weak relationship (r>0,3) (Cohen, 1988) with the total time they spend in the game.

Table 7. and Table 8. summarise the results of the research questions for a clear presentation. In the tables "+" and "-" indicate that there is and there is not a statistically significant relationship between two variables respectively, while "N/A" shows that such a result is not available as it has not been analysed in the study.

	Game Success (Score)	Total Game Time	Time in Game Scenarios	Time Spent for Answering Questions
Previous Gaming Habit	+	+	N/A	N/A
Previous Gaming Perception	+	-	N/A	N/A
Previous Theoretical Education	+	+	+	N/A
Perceived Difficulty	N/A	N/A	N/A	-
Perceived Motivation and Engagement	-	+	N/A	N/A
Intention on Future Use of SGs	-	N/A	N/A	N/A

Table 7. Availability of statistical relationship about gaming experiences

	Time in Game Scenarios	Time Spent for Answering Questions	Intention on Future Use of SGs	Perceived Game Effectiveness	Previous Gaming Perception
Game Success (Score)	+	+	N/A	N/A	N/A
Perceived Motivation and Engagement	N/A	N/A	+	+	+

Table 8. Availability of statistical relationship about gaming experiences and different variables

5. DISCUSSION

Serious games, as a technology-based method of learning, can provide maritime students in MET institutions with authentic interactive learning environments. Such environments can also contribute towards enhanced safety in maritime transportation through competency development. They also cause less risk and cost compared to onboard trainings. In addition, compared to simulators, they are cheaper, easier to maintain and therefore more accessible. Considering the significant potential serious games offer, facilitating their effective utilisation in maritime domain was the research objective of this study.

This study has provided some valuable insight into design and utilisation of maritime serious games. To start with, the study has proved that the number of gaming hours per week is related to the students' serious gaming success (RQ-1) and time spent in the serious game (RQ-2). Besides, it has also been shown that previous gaming perception of the students has statistically significant relationship with their serious gaming motivation (RQ-15) and success (RQ-3). From these findings, it can be claimed that students can potentially be more successful and learn better in serious games that are played on a voluntary basis.

In addition, the study also shows that the students who have previously taken leadership class have scored higher in the game (RQ-5) and spent more time in Level-3 (RQ-6). In this regard, it can be proposed that serious games might be useful if they are applied as a supplementary means of maritime education and training after the theoretical classes.

The study also illustrates that students who spend more time in the scenarios are more successful in all levels of the game (RQ-8). Besides, the students with higher motivation and engagement regard the game as more effective (RQ-14). These students also tend to spend more time in the game (RQ-16) and have higher intention concerning future use of similar serious games (RQ-13). Although the finding in RQ-11 seem to have weakened the argument that students with higher motivation and engagement can be more successful at the game, it is believed that serious games should be fun and engaging, so that the more time the students spend in the games, the more useful they are bound to be for them.

In fact, this study is the fundamental basis for our further development plan. Achieving the final version of the ML@S game by improving the prototype according to the feedbacks of this study constitutes the first step of our plan. In this regard, enhancing the graphics, modification of some scenarios in a way to make the questions more substantial, and adding more fun features, are among the planned improvements. Then the efficiency of the final version of the game will be re-analysed, along with a more comprehensive experimental study, according to which additional improvements to the final version of the ML@S game can also be made. Using the SGDM model, more maritime serious games will be designed and added to the Maritime Gamentor platform, which is being developed by Gurbuz and Celik (2022). Enhancing the SGDM model (if necessary), based on our experiences, will be the next step of our further development plan.

6. CONCLUSION

Serious games can provide maritime students and young seafarers with the practical education and training they need in a cost-effective way. It is believed that serious games have a significant potential for competency development in maritime domain. In this regard, the current study aims at providing a valuable insight into design and utilisation of maritime serious games by evaluating the ML@S game prototype.

This paper conducts a comprehensive experimental study for evaluating the effectiveness of a maritime serious game, namely Maritime Leaders at Sea (ML@S). For the evaluation process, this study proposes a methodology that utilises both traditional (pre/post survey) and evidence-based (learning analytics) methods. This methodology contributes towards filling the existing research gap in the maritime serious gaming literature. In fact, it is believed that employment of the methodology hereby proposed might also be extended to other domains.

Based on the survey answers, it may be concluded that the ML@S game prototype has been successfully tested by the students in all four categories (motivation and engagement, game effectiveness, game clearness, future use) as their average remarks have ranged between 'I slightly agree' and 'I agree'. Besides, important results regarding the utilisation of maritime serious games have been achieved as a result of the statistical analyses of the survey and gameplay data. The insight provided by this study can be followed by various maritime factors, such as game developers, technology start-ups, educational institutions, and global shipping companies, etc. for development and utilisation of future serious games aimed at enhancing essential skills of maritime human resources in dynamic and high-stakes environments.

In spite of the novel approach and significant potential of the study, there are some limitations worth mentioning. To start with, the evaluated version of the ML@S game is a prototype instead of the final version. In fact, the game prototype has been played by the students for the first time. This being the case, more dependable results might be achieved in a similar study conducted with later versions of the game. Although the collected data has passed the statistical sampling adequacy test, conducting the study with more participants might enable us to make a more accurate evaluation of the game, leading to more representative results.

LIST OF ABBREVIATIONS

AR: Augmented Reality
IMO: International Maritime Organisation
MET: Maritime Education and Training
ML@S: Maritime Leaders at Sea
RQ : Research Question
SGDM: Serious Game Design for Maritime
STCW: Standards of Training, Certification and Watchkeeping
VR: Virtual Reality

ACKNOWLEDGEMENT

This article is produced from initial stages of the PhD dissertation research entitled "A Conceptual Approach to Design and Development of Serious Games in Maritime Domain" which is being executed within a PhD Programme in Maritime Transportation Engineering of Istanbul Technical University Graduate School.

DECLARATION OF CONFLICTING INTEREST

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or non-profit sectors.

AUTHORSHIP

All authors have made substantial contributions in all parts of this research, including drafting and revising the manuscript, and have given their approval for its submission.

DATA AVAILABILITY

Data sharing is not applicable to this article as no new data has been created or analysed in this study.

DECLARATION OF ETHICAL STANDARDS

All procedures performed in this study are in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

DECLARATION OF INFORMED CONSENT

All participants have been fully informed about the study and a written informed consent has been obtained from all individual participants involved in the study

REFERENCES

Abt, C. C., 1970. Serious Game. Viking Press.

Ahir, K., Govani, K., Gajera, R. and Shah, M., 2020. Application on virtual reality for enhanced education learning, military training and sports. Augmented Human Research, 5, pp.1-9.

Akçayır, M. and Akçayır, G., 2017. Advantages and challenges associated with augmented reality for education: A systematic review of the literature. Educational research review, 20, pp.1-11.

Akyuz, E., & Celik, E., 2018. The role of human factor in maritime environment risk assessment: A practical application on Ballast Water Treatment (BWT) system in ship, Human and Ecological Risk Assessment: An International Journal, 24(3), pp. 653-666.

Alonso-Fernández, C., Calvo-Morata, A., Freire, M., Martínez-Ortiz, I., & Fernández-Manjón, 2023. Evidence-based evaluation of a serious game to increase bullying awareness, Interactive Learning Environments, 31(2), pp. 644-654.

Alyaz, Y., Spaniel-Weise, D., &Gursoy, E., 2017. A study on using serious games in teaching German as a foreign language. Journal of Education and Learning, 6(3), pp.250-264. Available at: https://eric.ed.gov/?id=EJ1141668.

Bai, S., Hew, K. F., & Huang, B., 2020. Does gamification improve student learning outcome? Evidence from a meta-analysis and synthesis of qualitative data in educational contexts, Educational Research Review, 30, 100322.

Bandara, D., Woodward, M., Chin, C. and Jiang, D., 2020. Augmented reality lights for compromised visibility navigation. Journal of Marine Science and Engineering, 8(12), p.1014.

Beavis, C., Muspratt, S., & Thompson, R., 2015. 'Computer games can get your brain working': student experience and perceptions of digital games in the classroom, Learning, media and technology, 40(1), pp. 21-42.

Bourgonjon, J., Valcke, M., Soetaert, R., & Schellens, T., 2010. Students' perceptions about the use of video games in the classroom, Computers & Education, 54(4), pp.1145-1156.

Bruzzone, A. G., Massei, M., Solis, A. O., Poggi, S., Bartolucci, C., & Capponi, L. D. A., 2013, July. Serious games as enablers for training and education on operations on ships and off-shore platforms, Proc. 2013 summer computer simulation conference, pp. 1-8.

Buzady, Z., Wimmer, A., Csesznak, A., & Szentesi, P., 2022. Exploring flow-promoting management and leadership skills via serious gaming. Interactive Learning Environments, pp.1-15.

Calderón, A., & Ruiz, M., 2015. A systematic literature review on serious games evaluation: An application to software project management, Computers & Education, 87, pp. 396–422. Available at: https://doi.org/10.1016/j.compedu.2015.07.011

Calvo-Morata, A., Freire-Moran, M., Martinez-Ortiz, I., & Fernandez-Manjon, B., 2019. Applicability of a cyberbullying videogame as a teacher tool: Comparing teachers and educational sciences students, IEEE Access, 7, pp. 55841–55850.

Cano, A. R., Fernández-Manjón, B., & García-Tejedor, Á. J., 2018. Using game learning analytics for validating the design of a learning game for adults with intellectual disabilities, British Journal of Educational Technology, 49(4), pp. 659-672.

Chang, A.H., Lin, P.C., Lin, P.C., Lin, Y.C., Kabasawa, Y., Lin, C.Y. and Huang, H.L., 2022. Effectiveness of virtual reality-based training on oral healthcare for disabled elderly persons: a randomized controlled trial. Journal of Personalized Medicine, 12(2), p.218.

Chae, C.J., Kim, D. and Lee, H.T., 2021. A study on the analysis of the effects of passenger ship abandonment training using VR. Applied Sciences, 11(13), p.5919.

Chow, C. Y., Riantiningtyas, R. R., Kanstrup, M. B., Papavasileiou, M., Liem, G. D., & Olsen, A., 2020. Can games change children's eating behaviour? A review of gamification and serious games, Food Quality and Preference, 80, 103823.

Cohen, J., 1988. Statistical power analysis for the behavioral sciences (2nd ed.), Hillside, NJ: Lawrence Erlbaum Associates.

Davis, F. D., 1985. A technology acceptance model for empirically testing new end-user information systems: Theory and results (Doctoral dissertation, Massachusetts Institute of Technology).

Davis, F. D., 1993. User acceptance of information technology: system characteristics, user perceptions and behavioral impacts, International journal of man-machine studies, 38(3), pp. 475-487.

Djaouti, D., Alvarez, J., & Jessel, J.-P., 2011. Classifying serious games: The G/P/S model. Handbook of Research on Improving Learning and Motivation through Educational Games, Multidisciplinary Approaches, 2, pp.118–136.

Fagan, M., Kilmon, C., & Pandey, V., 2012. Exploring the adoption of a virtual reality simulation: The role of perceived ease of use, perceived usefulness and personal innovativeness, Campus-Wide Information Systems, 29(2), pp.117-127.

Farrell, P. J., & Rogers-Stewart, K., 2006. Comprehensive study of tests for normality and symmetry: extending the Spiegelhalter test, Journal of Statistical Computation and Simulation, 76(9), pp. 803-816.

Fiellin, L. E., Hieftje, K. D., Pendergrass, T. M., Kyriakides, T. C., Duncan, L. R., Dziura, J. D., ... & Fiellin, D. A., 2017. Video game intervention for sexual risk reduction in minority adolescents: randomized controlled trial, Journal of medical Internet research, 19(9), e314.

Fotiadis, A. K., & Sigala, M., 2015. Developing a framework for designing an Events Management Training Simulation (EMTS), Journal of Hospitality, Leisure, Sport & Tourism Education, 16, pp. 59-71.

Fu, K., Hainey, T., & Baxter, G., 2016, October. A systematic literature review to identify empirical evidence on the use of computer games in business education and training. Proc. European Conference on Games Based Learning (p. 232). Academic Conferences International Limited.

Gray, S. I., Robertson, J., Manches, A., & Rajendran, G., 2019. Brainquest: The use of motivational design theories to create a cognitive training game supporting hot executive function, International Journal of Human Computer Studies, 127, pp. 124–149.

Gurbuz, S. C., & Celik, M.,2022. A preliminary design of a 3D maritime gamified mentoring platform to support tanker pre-vetting inspection training:'Maritime Gamentor', Ships and Offshore Structures, pp.1-11.

Gurbuz, S.C., 2021. A Conceptual Approach for Design and Development of Serious Games in Maritime Domain [Unpublished doctoral dissertation Progress Report-1, July 2021], Istanbul Technical University, İstanbul,Türkiye.

Hair, J. F., Hult, G. T. M., Ringle, C., & Sarstedt, M., 2014. A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM), Thousand Oaks, CA: SAGE Publishing.

Haruna, H., Zainuddin, Z., Mellecker, R. R., Kong, H., Chu, S. K. W., & Hu, X., 2019. An iterative process for developing digital gamified sexual health education for adolescent students in low-tech settings, Information and Learning Sciences, 120(11), pp.723–742.

Haruna, H., Zainuddin, Z., Okoye, K., Mellecker, R. R., Hu, X., Chu, S. K. W., & Hosseini, S., 2021. Improving instruction and sexual health literacy with serious games and gamification interventions: an outlook to students' learning outcomes and gender differences, Interactive Learning Environments, pp. 1-19.

ICS (International Chamber of Shipping), 2020. Annual Review 2020. Available at: https://www.ics-shipping.org/wp-content/uploads/2020/11/annual-review-2020-final-compressed.pdf, accessed on: 16 Oct 2023.

Kaufmann, D.A., 2018. Reflection: Benefits of gamification in online higher education. Journal of Instructional Research, 7, pp.125-132.

Lee, J., 2022. Problem-based gaming via an augmented reality mobile game and a printed game in foreign language education. Education and Information Technologies, 27(1), pp.743-771.

Lee, S.M. and Park, M., 2020. Reconceptualization of the context in language learning with a location-based AR app. Computer Assisted Language Learning, 33(8), pp.936-959.

Liu, M., Kang, J., Liu, S., Zou, W., & Hodson, J., 2017. Learning analytics as an assessment tool in serious games: A review of literature. In M. Ma & A. Oikonomou (Eds.), Serious games and edutainment applications, pp. 537–563: Springer International Publishing.

Long, P. D., Siemens, G., Conole, G., & Gašević, D., 2011. International Conference Proceeding Series (ICPS). Proc. 1st International Conference on Learning Analytics and Knowledge (LAK'11), NY, USA: ACM.

Luo, M., & Shin, S. H., 2019. Half-century research developments in maritime accidents: Future directions, Accident Analysis & Prevention, 123, pp. 448-460.

Mallam, S. C., Ernstsen, J., & Nazir, S., 2019, November. Safety in shipping: investigating safety climate in Norwegian maritime workers. Proc. Human Factors and Ergonomics Society Annual Meeting (Vol. 63, No. 1, pp. 1844-1848). Los Angeles, CA: SAGE Publications.

Margoudi, M., Oliveira, M., & Waddell, G., 2016, October. Game-based learning of musical instruments: A review and recommendations. Proc. European Conference on Games Based Learning, pp. 426: Academic Conferences International Limited.

Marín, B., Frez, J., Cruz-Lemus, J. and Genero, M., 2018. An empirical investigation on the benefits of gamification in programming courses. ACM Transactions on Computing Education (TOCE), 19(1), pp.1-22.

Michailidis, T., Meadow, G., Barlow, C. and Rajabally, E., 2020, September. Implementing remote audio as a diagnostics tool for maritime autonomous surface ships. In 2020 27th Conference of Open Innovations Association (FRUCT) (pp. 157-163). IEEE.

Mohamad, U.H., Ahmad, M.N., Benferdia, Y., Shapi'i, A. and Bajuri, M.Y., 2021. An overview of ontologies in virtual reality-based training for healthcare domain. Frontiers in Medicine, 8, p.698855.

Nikitakos, N., Sirris, I., Dalaklis, D., Papachristos, D., & Tsoukalas, V. D., 2017. Game-based learning for maritime education and training: the case of Trader of the World, WMU Journal of Maritime Affairs, 16, pp. 265-291.

Paolo, F., Gianfranco, F., Luca, F., Marco, M., Andrea, M., Francesco, M., ... & Patrizia, S., 2021. Investigating the role of the human element in maritime accidents using semi-supervised hierarchical methods, Transportation research procedia, 52, pp. 252-259.

Pellas, N., Fotaris, P., Kazanidis, I. and Wells, D., 2019. Augmenting the learning experience in primary and secondary school education: A systematic review of recent trends in augmented reality game-based learning. Virtual Reality, 23(4), pp.329-346.

Petri, G. and von Wangenheim, C.G., 2017. How games for computing education are evaluated? A systematic literature review. Computers & education, 107, pp.68-90.

Plotzky, C., Lindwedel, U., Bejan, A., König, P. and Kunze, C., 2021. Virtual reality in healthcare skills training: The effects of presence on acceptance and increase of knowledge. I-com, 20(1), pp.73-83.

Rao, M., 2014. Enhancing employability in engineering and management students through soft skills. Industrial and Commercial Training, 46(1), pp. 42-48.

Ranieri, M., Raffaghelli, J. E., & Bruni, I., 2021. Game-based student response system: Revisiting its potentials and criticalities in large-size classes, Active Learning in Higher Education, 22(2), pp. 129-142. Available at: https://doi.org/10.1177/1469787418812667.

Sardi, L., Idri, A., & Fernández-Alemán, J. L., 2017. A systematic review of gamification in e-Health. Journal of biomedical informatics, 71, pp. 31-48. Available at: https://doi.org/10.1016/j.jbi.2017.05.011.

Sartini, S., 2020. Kahoot in Maritime English Teaching: Its Impact on Nautical Science Cadet's Oral Reproduction and Vocabulary, English Language Teaching Educational Journal, 3(1), pp. 41-51.

Sekaran, U., & Bougie, R.,2016. Research methods for business: A skill building approach: John Wiley & Sons.

Sellberg, C., Lindmark, O., & Lundin, M., 2019. Certifying navigational skills: a video-based study on assessments in simulated environments, TransNav: International Journal on Marine Navigation and Safety of Sea Transportation,13.

Swacha, J., 2021. State of research on gamification in education: A bibliometric survey. Education Sciences, 11(2), p.69.

Teschner, J., 2016. Serious Games in Medical Education: As Learning Tools. Master's Thesis, University of Twente, Netherlands. Available at: http://purl.utwente.nl/essays/69684.

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B., 2013. Using multivariate statistics, Vol. 6, pp. 497-516, Boston, MA: Pearson.

Turner, P. E., Johnston, E., Kebritchi, M., Evans, S., & Heflich, D. A., 2018. Influence of online computer games on the academic achievement of nontraditional undergraduate students, Cogent Education, 5(1), 1437671.

Türkistanli, T. T., & Kuleyin, B., 2022. Game-based learning for better decision-making: A collision prevention training for maritime transportation engineering students, Computer Applications in Engineering Education, 30(3), pp. 917-933.

Udeozor, C., Russo Abegão, F., & Glassey, J., 2022. An evaluation of the relationship between perceptions and performance of students in a serious game, Journal of Educational Computing Research, 60(2), pp. 322-351.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D., 2003. User acceptance of information technology: Toward a unified view, MIS quarterly, pp. 425-478.

Wang, Q., & Abbas, M., 2018. Designing web-games for transportation engineering education, Computer Applications in Engineering Education, 26(5), pp. 1699-1710. Available at: https://doi.org/10.1002/cae.22031.

Weng, J. and Li, G., 2019. Exploring shipping accident contributory factors using association rules. Journal of Transportation Safety & Security, 11(1), pp.36-57.

Wronowski, M., Urick, A., Wilson, A. S., Thompson, W., Thomas, D., Wilson, S., ... & Ralston, R., 2020. Effect of a serious educational game on academic and affective outcomes for statistics instruction, Journal of Educational Computing Research, 57(8), pp. 2053-2084.

Ye, L., Zhou, X., Yang, S., & Hang, Y., 2022. Serious game design and learning effect verification supporting traditional pattern learning, Interactive Learning Environments, pp. 1-15.

Yeh, H.-C., & Tseng, S.-S., 2020. Enhancing multimodal literacy using augmented reality, Language Learning & Technology, 24(1), 27–37.

Yıldırım, İ., & Şen, S., 2019. The effects of gamification on students’ academic achievement: A meta-analysis study, Interactive Learning Environments, pp. 1-18.

Zainuddin, Z., Shujahat, M., Haruna, H., & Chu, S. K. W., 2020. The role of gamified e-quizzes on student learning and engagement: An interactive gamification solution for a formative assessment system, Computers & Education, 145, 103729. Available at: https://doi.org/10.1016/j.compedu.2019.103729.

Zimmerling, E., Höllig, C. E., Sandner, P. G., & Welpe, I. M., 2019. Exploring the influence of common game elements on ideation output and motivation, Journal of Business Research, 94, 302–312. https://doi.org/10.1016/j.jbusres.2018.02.030.

Appendix 1 ~ Survey Questions

Category	Survey Questions
Motivation and Engagement	**1.** I had fun playing the game
	2. I enjoyed playing ML@S serious game.
	3. I was highly engaged and involved in the game from beginning to the end.
	4. I stayed focused on the game from beginning to the end.
	5. I wish the game was longer.
	6. The game was exciting.
	7. Game graphics attracted my attention and enhanced my willingness to play.
Perceived Usefulness	**8.** The game has enhanced my leadership and team working skills.
	9. The game is useful for maritime education and training.
	10. The game will change my (future) leadership behaviors onboard ships.
	11. I think playing the game enabled me learn more quickly than theoretical education.
	12. ML@S serious game increased the quality of my learning experience.
	13. The game increased my interest in leadership and teamworking education.
	14. ML@S game fits well with the way I learn.
Perceived Ease of Use	**15.** I could easily understand the short scenarios in Level-2.
	16. The questions in Level-2 were easy.
	17. I could easily understand the scenario in Level-3.
	18. The questions in Level-3 were easy.
	19. The game was clear and understandable.
	20. It was easy for me to become in complete control of the game.
	21. I understood the game scenarios easily.
	22. I DID NOT feel any pressure or stress during the game.
	23. Considering all, the game was easy and not-challenging for me.
Intention on Future Use	**24.** I will use serious games for maritime education and training, if made available to me.
	25. I am open to using serious games to improve my leadership and teamworking skills, if made available to me.
	26. I would prefer playing similar games to theoretical education at school.
	27. I am excited about playing similar games at school.