ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

A CONCEPTUAL APPROACH FOR DESIGN AND DEVELOPMENT OF SERIOUS GAMES IN MARITIME DOMAIN

Ph.D. THESIS

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ISTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

DENİZCİLİK ALANINDA EĞİTİCİ OYUN DİZAYNI VE GELİŞTİRİLMESİ İÇİN KONSEPTSEL BİR YAKLAŞIM

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Süleyman Cihan GÜRBÜZ, a Ph.D. student of İTU Graduate School student ID 512182005, successfully defended the thesis/dissertation entitled "A CONCEPTUAL APPROACH FOR DESIGN AND DEVELOPMENT OF SERIOUS GAMES IN MARITIME DOMAIN", which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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To my spouse and child

FOREWORD

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Süleyman Cihan GÜRBÜZ
(Naval Officer)

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ABBREVIATIONS

AR : Augmented Reality

ANOVA : Analysis of Variance

CBT : Computer-based Training

HTMT : Heterotrait-Monotrait

IAPH : International Association of Ports and Harbors

ICS : International Chamber of Shipping

IMO : International Maritime Organization

KMO **:** Kaiser-Meyer-Olkin

MET : Maritime Education and Training

ML@S : Maritime Leaders at Sea

MR : Mixed Reality

MRA@S : Maritime Risk Assessment at Sea

OCIMF : Oil Companies International Marine Forum

RQ : Research Question

SG : Serious Game

SGDM : Serious Game Design for Maritime

SIRE : Ship Inspection Report

STCW : International Convention on Standards of Training, Certification and Watchkeeping

VR : Virtual Reality

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A CONCEPTUAL APPROACH FOR DESIGN AND DEVELOPMENT OF SERIOUS GAMES IN MARITIME DOMAIN

SUMMARY

Around 80,000 merchant vessels which are manned by about 1.6 million seafarers transport around 90 percent of world trading products. Transportation of important products such as food and medical supply during the Covid-19 pandemic has even spotlighted the vital role of seafarers.

International Convention on Standards of Training, Certification and Watchkeeping (STCW) (referred as STCW in this study), which has been issued by International Maritime Organization (IMO), defines the training and competency standards of the seafarers. It has been argued that there is an important gap between required on-board competency levels of seafarers and their actual levels of competency. Despite the regulatory and technological advancements in shipping, human error still plays a major role in more than 80% of shipping accidents.

For enhanced competency development of seafarers, maritime industry needs to find cheaper, accessible and more flexible methods of practical education and training. Serious gaming, as a technology-enabled instructional method, offers an important potential for maritime domain as it provides interactive and authentic learning environments.

In this regard, main objective of this study is proposing a holistic conceptual approach for effective design, development and utilization of serious games in maritime domain. More specifically, this study intends to provide the academicians and practitioners with a foundational basis for creating and using maritime serious games.

For this purpose, a systematic literature review on serious game design approaches with a special focus on future skill development is firstly conducted. In this review, 32 serious game design models which provide practical steps for serious game design are selected. It is found that 8 (25%) of these design approaches support at least one future skills, among which problem- solving as well as collaboration and teamwork are the most commonly supported ones. It is also discovered that clear goals and interactivity, used in 6 (75%) and 5 (63%) of the 8 design approaches respectively, are the most commonly implemented game design elements. Considering the significant literature gap on the implementation of serious games for future skills development, this literature review consequently provides valuable insights for the game designers, software developers, educational technology researchers, and engineering educators in various domains.

After that, Serious Game Design for Maritime (SGDM), a holistic model to support the design of maritime serious games is proposed. Using the SGDM model, MARITIME LEADERS at SEA (ML@S), a 3D serious game to enhance the leadership and teamwork skills of young seafarers and maritime students, has been prototyped. ML@S game is conceptualized as a module of the “Maritime Gamentor” platform.

Using the SGDM model, TASK-BASED RISK ASSESSMENT AT SEA (MRA@S) game is also designed and prototyped for task-based risk assessment training in preparation for the Ship Inspection Report (SIRE 2.0) inspections of Oil Companies International Marine Forum (OCIMF). Proposed model (SGDM) as well as the explained methodology can be followed by technology initiatives, game designers, and researchers for development of similar maritime serious game modules on soft skills and technical skills. Besides, functions of the Maritime Gamentor platform can be further extended in the maritime domain by adding similar serious game based training modules.

After prototyping the games, an experimental study was conducted for analyzing the efficiency of the ML@S game and proposed SGDM model. It can be concluded from the experimental study that the game was tested successful by the students in all 4 categories (motivation and engagement, game effectiveness, game clearness, future use). This being the case, it can be put forward that the developed ML@S game can be used as a means of leadership education and training. Looking at the broader picture in the study, it was proved that the SGDM model can be practically applied to design successful maritime serious games.

In sum, serious games can provide maritime students and young seafarers with the practical education and training they need in a cost effective way. For this reason, it is believed that the proposed approach can be followed by technology initiatives, game designers, and researchers for development of similar maritime serious game modules on soft skills and technical skills. Consequently, this research intents to contribute to safety, security and environmental protection in maritime domain by providing an insight into enhanced competency development.

DENİZCİLİK ALANINDA EĞİTİCİ OYUN DİZAYNI VE GELİŞTİRİLMESİ İÇİN KONSEPTSEL BİR YAKLAŞIM

ÖZET

Dünya genelinde yaklaşık 1.6 milyon denizci 80.000'in üzerinde gemi ile dünya genelindeki ticaret ürünlerinin yaklaşık %90'ının transferini gerçekleştşrmektedir. Bu rakamlardan denizcilerin dünya ticaret ve ekonomisindeki önemli rolleri anlaşılmaktadır. Covid-19 pandemisi sürecinde tıbbi malzeme, yiyecek malzemesi gibi önemli malzemelerin taşınmasındaki görevleri denizcilerin ve deniz ticaretinin hayatımızdaki rolünün daha da iyi anlaşılmasını sağlamıştır.

Denizcilerin sahip olmaları gereken minimum beceri standartları ile eğitimlerine yönelik birtakım standartlar Uluslararası Denizcilik Örgütü (IMO) tarafından hazırlanan Eğitim, Sertifikasyon ve Vardiya Standartları için Uluslararası Sözleşme-2010 (STCW-2010) ile belirlenmiştir. Ancak, meydana gelen deniz kazalarındaki insan hatalarının oranına da bakılarak gemide görev yapan denizcilerin sahip olmaları gereken becerilere gerçekte sahip olmadıkları ve bu nedenle STCW-2010'un günümüz şartlarına uygun olarak güncellenmesi gerektiği sıklıkla ileri sürülmektedir.

Denizciler gemide göreve başlamadan önce Denizcilik Fakültelerinde aldıkları teorik ve pratik eğitimlere ilave olarak gemilerde zorunlu staj eğitimi almaktadır. Alınan bu eğitimin öğrencileri gemideki görevlerine hazırlamada yetersiz kaldığı belirtilmektedir. Bunun nedenleri arasında öğrencilerin okuldaki teorik derslerin gemide direkt olarak işlerine yaramayacağını düşünmeleri nedeniyle bu derslere gereken önemi vermemeleri ve sınavlara çalışıp daha sonra bu bilgileri unutmaları gösterilebilir. Zorunlu gemi stajı faydalı bir periyot olmakla birlikte bu periyotta takip ve kontrol zorluğu nedeniyle uygulamada standardın sağlanması güçleşmekte ve bu da stajdan sağlanan faydayı kısıtlamaktadır.

Denizcilik Fakültelerinde verilen pratik eğitimlerde simülatörlerden sıklıkla faydalanılmaktadır. Simülatörler öğrencilere gerçeğe yakın eğitim ortamı sağlamaları açısından faydalıdır. Ancak öğrencilerin simülatörlere erişimlerinin ve simülatördeki senaryoların kısıtlı olması simülatörlerden elde edilen faydayı sınırlamaktadır. Simülatörlerin kurulum, bakım, işlerim gibi maaliyetlerinin fazlalığı da kullanımlarını kısıtlayan faktörlerdendir.

Denizciliğin emniyetli , güvenli, efektif ve çevre dostu olarak işletilmesi için denizcilik fakültesi öğrencileri ile genç denizcilerin pratik eğitimleri için yeni yöntemlere ihtiyaç duyulmaktadır. Arttırılmış Gerçeklik (AR), Sanal Gerçeklik (VR), Karışık Gerçeklik (MR) gibi teknoloji tabanlı eğitim yöntemleri sundukları ulaşılabilir ve gerçekçi

uygulamalar ile denizcilik sektörünün bu ihtiyacının karşılanmasında faydalı olabilecekleri değerlendirilmektedir.

Eğitici oyunlar temel amacı eğlenceden ziyade eğitim olan oyunlar olarak tanımlanabilir. Oyun öğelerinin eğitim maksadıyla kullanılmasının öğrencilerin katılım ve motivasyonunu arttırdığı, davranışsal değişikliği kolaylaştırdığı, eleştirel düşünmeyi geliştirdiği ve daha kalıcı öğrenmeyi sağladığı belirtilmektedir.

Eğitici oyunlar son 10 yılda başta eğitim, sağlık, iş yönetimi, dil öğrenimi, spor, müzik gibi alanlar olmak üzere birçok alanda popularite kazanmıştır.

Eğitici oyunlar teknoloji tabanlı eğitim metodu olarak denizcilik sektörünün göreve yönelik eğitim ihtiyacının karşılanmasında önemli bir potansiyele sahiptir. Eğitici oyunların gerçekçi eğitim ortamı sunmaları ve bilgisayar, telefon, tablet gibi taşınabilir cihazlardan göreceli olarak düşük maliyetlerle ulaşılabilir olmaları bu potansiyeli oluşturan nedenlerin başında gelmektedir.

Bu çalışmanın temel amacı eğitici oyunların denizcilik alanında daha efektif ve yaygın olarak kullanılmasına katkı sağlamaktır. Bu çerçevede, çalışmada denizcilik alanında kullanılacak eğitici oyunların tasarımı ve geliştirilmesi için bütüncül ve uyarlanabilir bir konseptsel yaklaşım önerilmiştir.

Çalışma kapsamında öncelikle eğitici oyun dizayn metodlarına yönelik sistematik bir literatür taraması yapılmıştır. Literatür taramasında dizayn metodlarının 21.yüzyılda ihtiyaç duyulan becerilerin gelişimine katkıları da incelenmiştir. Bu taramada eğitici oyun dizaynı için gerekli adımları öneren toplam 32 adet dizayn yöntemi bulunmuştur. Bu yöntemlerden 8 (%25) tanesinin 21. yüzyıl becerilerinden en az 1 tanesini desteklediği ve en çok desteklenen becerilerin problem çözme ile yardımlaşma ve takım çalışması olduğu tespit edilmiştir. Ayrıca açık hedefler ve interaktivitenin bu 8 yöntemin sırasıyla 6 (%75) ve 5 (%63)'inde kullanılarak en çok kullanılan oyun dizayn elementi olduğu bulunmuştur. İlave olarak, bulunan 32 adet yöntem hedeflenen sonuçlara göre gruplandırılmıştır. Bu yöntemlerden 12 (%38), 4 (%13) ve 2 (%6) tanesinin sırasıyla öğrenme, davranışsal ve motivasyonel sonuçları, 14 (%43) tanesinin ise bu sonuçlardan birden fazlasını hedeflediği görülmüştür.

Literatür çalışmasında tespit edilen 32 adet eğitici oyun dizayn yönteminin 22 (%69) tanesinin eğitim, 5 (%16) tanesinin sağlık, 2 (%16) tanesinin askeri ve 1'er tanesinin turizm, karar verme ve siber güvenlik alanlarında oyun dizaynına yönelik olduğu görülmüştür. Bu kapsamda, spesifik alanlara özel eğitici oyun dizayn modellerine ihtiyaç duyulduğu ve bahse konu modellerin o alanda daha etkili eğitici oyun tasarımına olanak sağlayabileceği değerlendirilmektedir. Literatür taramasında ortaya konan sonuçların oyun tasarımı, yazılım geliştirme, eğitim teknolojileri araştırmaları, mühendislik eğitimi gibi çeşitli alanlara katkı sağlayacağı değerlendirilmektedir.

Sistematik literatür taramasında tespit edilen ihtiyacın karşılanması maksadıyla bu çalışmada öncelikle denizcilik alanına özel bir eğitici oyun dizayn modeli olan **S**erious **G**ame **D**esign for **M**aritime (SGDM) modeli ortaya konulmuştur. Bu model 8 adımdan oluşmaktadır. Bu adımlar eğitici oyunun konu ve hedef kitlesinin belirlenmesi, eğitim hedeflerinin belirlenmesi, eğitim hedeflerinin gözlemlenebilir davranışlar/beceriler olarak ifade edilmesi, davranış/becerilerin karmaşıklık seviyelerine göre 4 gruba ayrılması, her grup için gerçekçi senaryoların oluşturulması, ipuçları ve geri beslemelerin eklenmesi, değerlendirme kriterlerinin eklenmesi ve dizaynın kontrol edilerek sonlandırılmasıdır.

SGDM modelinin girdisi bir eğitici oyun fikri çıktısı ise eğitici oyun dizaynıdır. SGDM modeli bütüncül bir modeldir ve konusu ve kapsamı ne olursa olsun denizcilik alanındaki tüm eğitici oyunlar için uygulanabilir. Çalışmada tespit edilebildiği kadarıyla literatürde denizcilik alanına özel bir eğitici oyun dizayn modeli bulunmamakta olup SGDM nin bu alanda ilk model olduğu değerlendirilmektedir.

Denizciliğe yönelik eğitici oyun tasarımında SGDM modelinin kullanılmasının birtakım avantajları mevcuttur. Öncelikle SGDM modeli eğitici oyun dizaynı için, tespit edilen birçok modelin aksine, adım adım ve somut bir yönlendirme sağlamaktadır. Ayrıca SGDM modeli denizciliğin ihtiyacını karşılayacak şekilde pratik becerilere yönelik ve gerçekçi eğitimler tasarlanmasına yardımcı olmak maksadıyla geliştirilmiştir. Bu kapsamda SGDM modeli senaryo bazlı öğrenme, deneysel öğrenme, eğitimsel uyumlaştırma gibi öğrenme metodlarını kullanmaktadır.

SGDM modelinin ortaya konmasını müteakip bu modelin uygulaması olarak 2 adet eğitici oyun tasarımı gerçekleştirilmiştir. "Maritime Leaders at Sea" (ML@S) adındaki birinci oyun STCW kapsamında liderlik ve takım çalışması eğitimini amaçlamaktadır. ML@S senaryosu bir ticari geminin köprüüstünde geçmekte ve oyuncu kaptan rolünde oynamaktadır.

ML@S oyunu basitten zora doğru ilerleyen 3 bölümden oluşmaktadır. Birinci bölümde 4 adet teorik soru cevaplanmaktadır. İkinci bölümde 5 adet kısa senaryo yer almaktadır. Oyuncunun bu senaryolarda oyunun diğer aktörleri olan 3. Kaptan, serdümen ve gözcüye karşı davranışları onların üçüncü bölümdeki performansını etkileyecektir. Üçüncü bölümde ise 2 adet farklı geminin de yer aldığı uzun bir senaryo mevcuttur. Oyuncunun oyunu kazanması için 70 puan barajını aşması ve oyunun sonunda diğer gemi ile çarpışmayı önleyebilmesi gerekmektedir.

Tasarımı yapılan ikinci oyun ise "Maritime Risk Assessment at Sea" (MRA@S) isminde bir görev bazlı risk analizi oyunudur. Oyun tanker gemisi personelinin SIRE denetlemesine hazırlanmasında kullanılmakta olup senaryosu kapalı mahale giriş öncesinde yapılan bir risk analiz toplantısında gerçekleşmektedir. MRA@S oyunu 4 bölümde toplam 11 adet kısa senaryodan oluşmaktadır. Oyunun kazanılması için 70 puanın aşılması gerekmektedir.

Tasarlanan oyunların hayata geçirilmesi için Unity 3D® oyun motoru kullanılmıştır. Bu oyun motoruyla oyunların ön geliştirilmesi yapılmış, daha sonra öğrenci ve akademik personelden alınan fkirler doğrultusunda oyunlar geliştirilmiştir. Oyunlar internet üzerinde oluşturulan "Maritime Gamentor" isimli platforma 2 adet modül olarak yüklenmiştir. Oyunlar halihazırda gerek bu platform üzerinden, gerekse oyun dosyasının bilgisayara aktarılması ile Windows ve Mac platformlarından oynanabilmektedir.

Çalışmanın bu bölüme kadar olan kısmında dizayn sonucunda elde edilen tecrübeler vasıtasıyla mevcut sorunlara çözümler bulmayı amaçlayan araştırma yöntemi olan dizayn bazlı araştırma yöntemi kullanılmıştır. Bu kapsamda oyunların fiilen tasarlanıp geliştirilmesinden icra edilen tecrübeler çalışmada yer almıştır. İlave olarak, çalışmada denizcilik alanında eğitici oyunların tasarım ve geliştirilmesi maksadıyla kullanılabilecek bütüncül ve uygulanabilir bir metodoloji önerilmiştir. Bu nedenlerle çalışmanın hem teorik hem de pratik açılardan önemli katkılar sağladığı değerlendirilmektedir.

ML@S ve MRA@S oyunlarının geliştirilmesinden sonra yapılan deneysel çalışma ile ML@S oyununun etkinliği incelenmiştir. Bu kapsamda öncelikle İTÜ Denizcilik

Fakültesinden 76 öğrenciye oyun oynatılmıştır. "Öğrenme Analitiği" yaklaşımı ile öğrencilerin oyun süresince geçirdikleri süre ve kaybettikleri puanlar da kaydedilmiştir. Öğrencilerin puan ortalaması 86,75 başarı yüzdesi ise %100 olarak gerçekleşmiştir. Oyun hitamında anket ile öğrencilerin görüşleri alınmıştır. Deneysel çalışma 3 farklı oturumda çevrimiçi olarak gerçekleştirilmiştir.

Daha sonra anket sonuçları ve oyun esnasında kaydedilen puan ve süre verileri SPSS 28® yazılımı kullanılarak analiz edilmiştir. Yapılan analiz sonucunda eğitici oyunların uygulanmasına yönelik önemli bulgulara ulaşılmıştır. İlk olarak, daha çok oyun oynayan öğrenciler eğitici oyunda daha iyi motive olup daha başarılı olmuştur. Bu bulguya dayanarak eğitici oyunların gönüllülük esasına göre uygulanmasının oyunlardan elde edilen faydayı arttırabileceği değerlendirilmektedir. Ayrıca, daha önce teorik liderlik dersi alan öğrencilerin ML@S oyununda daha yüksek puan aldıkları tespit edilmiştir. Bu tespite dayanarak eğitici oyunların teorik derslerin yanında yardımcı bir yöntem olarak uygulanabileceği düşünülmektedir.

İstatistiksel analiz sonucunda elde edilen bulgulardan birisi de oyundaki senaryolarda daha fazla zaman geçiren oyuncuların daha yüksek sonuçlar aldığıdır. Ayrıca, öğrencilerin oyun öncesindeki motivasyonunun oyun senaryolarında geçirilen süre ve benzer oyunları tekrar oynama isteğini arttırdığı tespit edilmiştir. Bu kapsamda, eğitici oyunların eğlenceli ve cezbedici olmasının öğrencilerin sağladığı faydayı arttırabileceği düşünülmektedir.

Sonuç olarak, bu çalışmada denizcilik alanındaki eğitici oyunların gerek tasarımı ve geliştirilmesi gerekse uygulanması konularında konseptsel bir yaklaşım ortaya konulmuştur. Bu nedenle çalışmanın bütüncül bir yaklaşıma sahip olduğu ve benzer çalışmaların yapılmasına da katkı sağlayabileceği değerlendirilmektedir. Çalışmadan eğitici oyun şirketleri, araştırmacılar, denizcilik şirketleri, fakülteler gibi çeşitli aktörler tarafından faydalanılabileceği düşünülmektedir.

1. INTRODUCTION

1.1 Background

In spite of the advancing technology and regulatory updates, human error still is the main reason for more than 80% of shipping accidents (Akyuz and Celik, 2018). Well-trained, competent and experienced seafarers are of vital importance for safety and efficiency of shipping (Lewin, 2015). In fact, sailing has long been learned through practical apprenticeship from more experienced sailors. Making novice seafarers perform duties onboard ships has traditionally been a common method of training. As such, practical onboard training is the primary method of competency development of maritime students and young seafarers.

International Conventions on Standards of Training, Certification and Watchkeeping (STCW) conventions, which have been issued by International Maritime Organization (IMO), define the training and competency standards of the seafarers. STCW 2010 Convention, as the current regulatory document in Maritime Education and Training (MET), sets up a competency-based training model comprising of a synthesis of college education and training as well as practical training onboard ship (IMO, 2013).

Although being the fundamental method, practical onboard training has some drawbacks that restrain it from reaching the targeted outcomes. To start with, as operating a ship for training purposes is costly and risky, onboard training time per student is not always enough to provide detailed personalized training. The lack of consistent procedures on cadetship training onboard ships is another factor that might limit the targeted competency development (Mazhari, 2018). This being the case, maritime domain needs to find cheaper, easier and more flexible methods of practical competency development for increasing the efficiency of onboard trainings and thus the efficiency of MET in general.

In this regard, it can be put forward that online learning methods must be utilized effectively for limiting the drawbacks of onboard trainings and increasing their efficiency. STCW 2010 Convention (Section B-I/6) states that maritime authorities may allow the training of seafarers by distance learning and e-learning in accordance with the standards of training and assessment and the guidance provided in the same section (IMO, 2013). In maritime institutions, online trainings, assessments and computer-based knowledge management systems, which allow students to use resources, such as audios, videos, or online books from their own computers within campus or at home using internet or private networks are already playing important roles (Mazhari, 2018). Although allowed by the convention and being applied in practice, it is regarded that there are no well-defined standards for the implementation of online learning in MET.

In fact, technology enhanced online learning methods have a more important potential than before mentioned regular online learning applications for maritime domain as these methods are more capable of offering practical competency development experiences. As such methods, serious games which are defined as games developed for educational purposes (Djaouti et al, 2011) can be used to enhance the effectiveness of education and training in MET institutions through active learning environments no matter where the students are (Bruzzone et al, 2013).

1.2 Motivation

Development of practical skills among seafarers around the world is indispensible for safety and efficiency of maritime transportation as well as environmental protection. With the advancing technology onboard ships and increasing need for maritime transportation, it is not difficult to foresee that the demand for skilled seafarers will even prevail. For fulfilling the increasing demand, maritime industry needs to utilize online learning methods more effectively together with onboard trainings. The Covid-19 Pandemic which struck almost the whole world also highlighted the importance of online maritime trainings, as well as online trainings in general.

Serious games, as technology enabled methods of online learning, has been gaining popularity in various domains such as healthcare, education, business etc. However, it is surprising to see that serious gaming in maritime domain is still at early stages. Although there are commercially available maritime serious games, they are not

widely accessible by seafarers or maritime students for competency development. It is regarded that increased number of scientific studies on serious gaming in maritime domain as well as closer coordination between the academia and maritime industry might increase the availability and utilization of maritime serious games.

With this perspective, the motivation of this study is obtaining attention of the academia and thus contributing to increased number of scientific studies on the topic. It is believed that increased scientific popularity might induce closer coordination with the industry and facilitate wider development and utilization of maritime serious games within the domain. I hope this study can serve as a starting point for this chain reaction towards widespread utilization of serious games in MET.

1.3 Research Gap

Regardless of the popularity of serious games and the significant potential they offer, the literature still needs studies on their design, development, and utilization in the maritime domain. Firstly, additional studies are needed about the role and efficiency of serious game design models on development of future skills. Such a study on serious game design models in general might shed important light into design of maritime serious games and how they can facilitate development of maritime future skills.

In addition, a serious game design model which is specific to maritime domain is needed in the literature. Maritime domain is unique with its own dynamics and reqirements for extensive practical skills. This being the case, a serious game design model created for fulfilling the specific needs of the domain might facilitate design of effective maritime serious games.

Besides, the literature also lacks a study which provides step by step practical guidance for design and development of maritime serious games. Existing maritime serious gaming literature mostly focus on the role and effectiveness of such games rather than the design and development process. For this reason, it is regarded that scientific studies which can guide design and development of future maritime serious games are needed.

Finally, as serious gaming in maritime domain is a subject with limited research, experimental studies analyzing the experiences and perceptions of maritime students on maritime serious games are also limited. It is believed that such studies might be

useful not only for enhancing the effectiveness of maritime serious games but also for shedding light into their effective utilization within MET practices.

1.4 Aim and Research Questions

This study intents to contribute in closing the before mentioned research gaps regarding the serious gaming in maritime domain. With this perspective, main objective of this study is proposing a holistic conceptual approach for effective design, development and utilization of serious games in maritime domain. More specifically, this study aims to provide the academicians and practitioners with a foundational basis for creating and using maritime serious games.

For achieving the main objective, current study aims to answer the following research questions:

Research Question-1: Which learning theories and game design elements are used by serious game design approaches for future skills development?

Research Question-2: Which learning theories and game design elements should be used for designing maritime serious games?

Research Question-3: How should these theories and elements be combined together for proposing a serious game design model which is specific to maritime domain?

Research Question-4: Can the proposed model be actually used for designing maritime serious games?

Research Question-5: What are the experiences and perceptions of undergraduate maritime students towards the prototyped Maritime Leaders at Sea (ML@S) game as well as maritime serious games in general?

1.5 Research Contribution

It is believed that current study offers significant theoretical and practical contributions to maritime literature. To start with, through the systematic literature review of the serious game design models, this study enhances our theoretical knowledge and understanding on serious game design approaches. In fact, the literature review conducted for the purpose of this study differentiates from previous

studies in providing a review of the serious game design approaches with a special focus on how they support development of future skills.

Based on the findings from the literature review, this study offers **S**erious **G**ame **D**esign for **M**aritime (SGDM) serious game design model. SGDM is regarded to be the first serious game design model created specifically for the maritime domain. Because SGDM model employs the learning theories and gaming elements that are selected specifically for the maritime domain, it is believed to be able to facilitate the design of more effective maritime serious games.

This study also proposes a holistic and applicable methodology for the design and development of maritime serious games. The proposed methodology can be benefited both by the industry and academic researchers for design and development of future maritime serious games. Besides, current study prototypes two maritime serious games which have the potential to be used for education and training of students in maritime faculties as well as in cadetship training programs of young seafarers by maritime companies. Finally, this study performs a comprehensive experimental study using the learning analytics perspective. The experimental study also provided us with some valuable insight into design and utilization of maritime serious games.

In sum, providing a holistic and applicable conceptual approach, this study proposes a foundational basis for design, development, and utilization of maritime serious games. Considering the significant potential serious games offer, it is believed that such a basis has been an urgent need for maritime domain.

1.6 Research Structure

For achieving the main objective, this study is structured as follows:

Chapter-1 presents a general introduction about the research topic. For this purpose, a background information about the topic is firstly provided. Then, the motivation of the study is summarized. This chapter also includes the research gaps this study intents to contribute in closing. After that, research aim and the research questions which this study aims to answer are explained. Finally, contribution and an overview of the research organization and design are also provided in the chapter.

Chapter-2 provides a comprehensive theoretical background through literature review. This chapter firstly presents a systematic literature review on serious game

design models with a special focus on future skills development. The systematic literature review is conducted in accordance with the guidelines provided by Kitchenham (2004) and Kitchenham and Charters (2007). This chapter also includes a literature review on MET as well as a critical review of the provided literature.

Chapter-3 explains the methodology of the study. This study utilizes a design based research method, which intents to enhance educational practices through analysis, design, development and implementation (Wang and Hannafin, 2005). This chapter, after proposing the SGDM model, explains the design of 2 serious games using the model. Prototyping of both games are also included in the chapter.

Chapter-4 presents the experimental study conducted for assesing and validating the prototyped ML@S game. This quantitative experimental study took the survey and correlational research approach (Creswell, 2009) where experiences and perceptions of the students are evaluated through a survey and the correlation between them is statistically analyzed.

Chapter-5 explains the results of the statistical analysis performed for answering the Research Question-5. A detailed discussion regarding the acquired results within the perspective of the overall study is also presented in the chapter.

Chapter-6 provides the conclusion, research limitations and future work planned to be conducted for minimizing these limitations.

2. LITERATURE REVIEW

2.1 Maritime Education and Training (MET)

Seafarers have been sailing at seas for trade for a long time. Well-trained, and competent seafarers are of vital importance for safe and effective operation of shipping (Lewin, 2015). They have traditionally been learning this profession from more experienced sailors at sea. Performing a duty on ship has always been a common method of training in navigation. Kennerly (2002) reports that success in seafaring, among other technical factors, severely depends on experience.

Towards the end of 19th century, with the establishment of first maritime training schools, maritime education and training (MET) started to become more systematized. Some of these schools were managed by governments and others were managed by the maritime industry. But, starting from 1950s, additional concerns about the efficiency of MET practices have been raised by governments and maritime stakeholders. Additionally, more internationalized structure of maritime domain fostered the concerns about the educational and competency levels and standards of seafarers (Kennerly, 2002).

Massive changes in ship types and size as well as electronic systems, equipment and technology occurred around 1960s. Ships with special purposes, increase in size of the ships, the birth of various electronic aids and systems as well as trends towards automation necessitated significant enhancements in MET practices so that seafarers are able to deal with the changing needs of the domain. It can be put forward that the maritime industry will continue to change, causing the need of enhancement in MET practices prevail (Fuazudeen, 2008).

After 1980s, increase in globalization and overseas trade gained an important momentum. This momentum, coincided with increased number of catastrophic

maritime accidents, intensified the need for competent maritime labor force. This is the period when major regulations in maritime domain have been made. International Maritime Organization (IMO), which is the main policy maker in maritime domain, decided to make comprehensive advancements and acquire standardization in MET (IMO, 2023).

2.1.1 International regulations in MET

IMO (then IMCO) organized the "International Conference on the Safety of life at Sea" in 1960, which can be considered as the first major act for ensuring safety at sea. As a result of this conference, governments were invited to take applicable measures for guaranteeing educations and trainings of seafarers. After this conference, IMO founded Maritime Safety Committee (MSC), who published some guidance for education and trainings of seafarers in 1964 (IMO, 2023).

At that time, standards in MET were very different since countries were applying their own standards. In 1971, IMO decided that an international regulation is needed so that more powerful and comprehensive measures could be applied. Then, IMO Sub-Committee on Standards of Training and Watchkeeping created a draft resolution and in 1978, The International Convention on Standards of Training Certification and Watchkeeping for Seafarers, STCW 1978 was adapted (IMCO, 1978).

2.1.1.1 STCW 1978 convention

STCW 1978 Convention was an important step in standardization of MET. The standard set by the Convention applies to all seafarers serving on seagoing merchant vessels under the flag of a country that signed the convention. However, The STCW 78 Convention does not apply to seafarers serving on warships or any other government owned or operated non-commercial ships, fishing vessels and pleasure yachts not engaged in trade. The Convention entered into force on 28 April 1984 after being approved by 144 countries with 98.45 % of the world's fleet tonnage.

With a total of 6 chapters and 23 resolutions, the Convention defines training standards as well as providing recommendatory details to further explain the mandatory provisions. The Convention also settles the fundamental principles, rules and responsibilities about navigation and navigational watch. It is further stated in the convention that candidates must be successful at examinations about many topics such

as navigational competency, damage control, cargo handling, ship stability, fire prevention, communication, search and rescue etc. with different requirements according to tonnage of the ship. Similarly, the chapter for the engine department also defines the main rules for maintaining an engineering watch, with changing requirements with respect to the engine power. The convention also explains the compulsory provisions about safe radio watchkeeping and maintenance, which are also included in SOLAS. Moreover, the convention brings some additional requirements for tanker crew such as fire-fighting course and minimum ship duty period (IMO, 2001).

Despite its worldwide utilization, it was figured out by the late 1980s that the convention was failing to achieve its intended purpose (Ghosh et al, 2014). The main reason for this failure was that the standards were not clear and precise enough to be applied in the same way by all countries. For instance, although minimum period of seagoing service and knowledge requirements were defined, they could not be applied in the same way by all countries since the required competencies were not defined (Emad, 2011). Although it could not be effectively applied for a long time, the 1978 Convention is an important step for MET since it is the first global attempt to define standards for seafarers (IMO, 2001).

2.1.1.2 STCW 1995 convention

Because of increasing number of maritime accidents, IMO created another draft convention, with the purpose of eliminating the drawbacks of STCW 78. The main targets of new convention were (IMO, 2011, p.28);

Clearly explaining the required skills and competencies,

Authorizing maritime administrations of countries directly inspect qualifications of crew,

Making maritime administrations responsible to each other for the efficient application of the convention,

Ensuring that the convention came into force as soon as possible.

STCW 95 Convention, came into force in February 1997, comprises of two parts; Part A and Part B. Part A defines obligatory requirements while Part B explains non-obligatory guidelines.

STCW 95 highlighted outcome-based practices on training of seafarers, which means they were required to demonstrate the ability of performing a duty, rather than just having the knowledge Using Computer-based training (CBT) method in MET was also introduced in STCW 95. With the proper utilization of CBT method, on-board trainings were allowed to be replaced by simulator and workshop practices (IMO, 2011).

Main failure of STCW 95 was that it could not effectively addressed the requirements of developing maritime technology. This means education and training needs for safety, efficiency and environmental protection could not be fully met in the convention. For eliminating this limitation, maritime actors placed their urgent demands. Until 2006, it was amended several times but the shortcomings prevailed. For this reason, IMO took a comprehensive action in 2006, with the revision of the whole convention. This action led to STCW 2010, Manila amendments (IMO, 2011).

2.1.1.3 STCW 2010 convention

For a comprehensive review to STCW 95 Convention, a conference with all parties was held in Manila, Philippines between 21 and 25th of June in 2010. As a result of this conference Manila amendments which entered into force on 1 January 2012 were decided (IMO, 2011). Evans et al. (2017, p.8) summarized the main changes to STCW 95 as follows:

> New training guidance for officers and ratings.
>
> New training requirements for leadership and teamwork.
> New measures to avoid 'fatigue' through modifications to the minimum rest hours of seafarers on board.
> Introduction of new training requirements of electro-technical officers.
>
> Increasing the shipboard training requirements of the engine department cadets.
>
> Changes to the 'drugs and alcohol policy' and medical examination of seafarers.
>
> Introduction of the Able Seaman training requirements and certificate of competency (in harmony with the ILO requirements for Able Seaman).

New training requirements for Electronic Chart Display and Information System (ECDIS).

New competency requirements for seafarers serving on board oil tankers, gas carriers, chemical carriers, ships operating in polar waters and ships with dynamic positioning systems.

STCW 2010 has a much stronger focus on practical competency than previous STCW conventions. STCW 78 stressed the importance of having knowledge, while the focus actually shifted to the concept of competency in STCW 1995. But STCW 2010 stressed the importance of practical abilities and competency much more effectively compared to STCW 95. Another aspect that STCW 2010 emphasized more strongly than STCW 95 was the use of technology in MET. The use of computer-based training and simulation practices have been regulated in STCW 2010 in a way to encourage wide application of them (Evans et al, 2017).

STCW 2010 also includes some regulations for the safety and health of the crew on board. Preventing fraud in certificates, work and rest hour regulations, modernized medical fitness standards and enhanced security training standards for the safety of crew are among regulations conducted for this purpose (IMO, 2022).

However, it is suggested that STCW 2010 are not capable of meeting maritime industry needs and thus needs to be updated (ICS, 2020). It is suggested that governments' control and application of the convention must be clarified. Specifically, it is explained that IMO must make more rigid legal regulations which can ensure close governmental control on MET institutions. It is additionally explained that a comprehensive revision of STCW 2010 is necessary so that it adapt to changing training needs resulting from the current technological developments and environmental regulations in the industry. It is further put forward that many maritime companies need to provide additional maritime education and trainings to seafarers who are already certified in compliance with STCW 2010, which shows that STCW 2010 is not able to provide the necessary basis for training of seafarers (ICS, 2020).

2.1.2 Collage-based maritime education and training

Maritime students need to complete specialized education and training to become so competent as serve onboard ships. The required education and training consists of college-based education and training and practical training on board ship (IMO, 1996).

College-based curricula primarily includes classroom-based theoretical education as well as simulator and workshop training for developing practical skills. Collage-based MET aims to teach the knowledge and understanding required by the students to accomplish their duties onboard ships. The main purpose of collage-based MET is to provide the students with the theoretical knowledge they need on-board ships. However, it cannot always achieve this purpose efficiently. One of the main reason for this failure is the certification system and the way its competency assessment practices are organized by maritime administrations. What is taught and what is asked in examinations in maritime colleges do not correlate with what is required onboard ships. For this reason, students focus to pass the tests, rather than developing competency for on-board duties as they know the lessons at school will not help them very much developing these competencies (Emad, 2011).

Minimum level of competency that maritime colleges need to provide is not defined by maritime authorities. For this reason, students in maritime colleges might consider this period just as a compulsory education to finish, rather than a period to gain competency for their on board duties. Additionally, without mandatory competency standards, both maritime college teachers and students might have a tendency to think that students will already have enough training time after college to gain necessary competency for their on-board duties, which might limit the effectiveness of college education. Likewise, there are not defined standards for assessments in maritime colleges. Assessments in maritime colleges might be conducted in various ways, from multiple choice to practical tests in simulators. Lack of standards in collage-based MET might limit the educational quality in maritime colleges around the World (Mazhari, 2018).

In college-based trainings, there are some technical courses which are mandatory for certification of students. Emad (2011) states that these courses, which mostly focus on specialized aspects of on-board duty like emergency procedures, safety etc., are generally found satisfying and regarded as motivational by students. As these technical courses require students to reach a pre-defined competency levels on topics which are directly needed during on-board duties, it is believed that they are in compliance with competency-based training targets defined by STCW 2010. However, it is regarded that colleges providing such trainings must be authorized by maritime administration of countries in order to keep the quality standard (Emad, 2011).

Considering all, practical trainings in maritime colleges can be considered successful in reaching their objectives. However, because their duration is limited, the college-based trainings might be able to cover only some of the skills that seafarers will need on-board ships. As a result, the training in the colleges by itself, although effective, may not close the existing gaps between what is learned by college training and what is needed on the job. Considering all, it is concluded that practical trainings should be given higher priority in maritime colleges in order to provide maritime students with desired competencies they need onboard ships (Mazhari, 2018).

2.1.3 Shipboard training

In shipboard training, maritime cadets receive practical training onboard ships about competencies required for their future duties. During this period, cadets have a training record book including their target knowledge/competencies and shipboard officers are supposed to train them accordingly.

The standards regarding on-board trainings have been included in STCW 2010. It is stated in Section A-II/1 of STCW 2010 that candidates are required to accomplish a minimum period of seagoing service for certification as officer in charge of a navigational watch of ships of 500 gross tonnage or more. It is further required by the same section that the candidate receives systematic practical training and experience, being closely supervised and adequately documented. Similarly, as stated in Section A-III/1, for certification as officer in charge of an engineering watch on ships with main propulsion machinery of 750 kW, minimum periods of seagoing services with on-board trainings are required, being closely supervised and adequately documented (IMO, 2011).

On-board trainings are generally considered as the most effective part of MET as they aim to develop the specific competencies seafarers need during their on-board duties. In spite of their significant potential, unstandardized applications which result from inadequate supervision and control over seafarers might limit their efficiency, making their learning outcomes unpredictable. To overcome this potential problem and ensuring the effectiveness of on-board trainings, close coordination between shipping companies and training institutes in required (Lewarn, 2002).

In sum, MET is currently guided by international maritime regulations, STCW 2010 being the main regulatory document. These regulations define minimum competency-

based standards that seafarers need to have so that they are internationally qualified and certified. Signatory countries have to inspect the compliance of MET applications in their countries to these standards (IMO, 2022). For maritime safety, security and environmental protection, the STCW-compliant MET is of vital importance. It is critical that MET provides young seafarers with technical skills as well as soft skills such as maintaining situational awareness, risk management, problem solving, leadership and teamwork (Basak, 2017). In fact, existence of maritime accidents and incidents due to human error show that MET needs to be enhanced so that young sefarers is proven to have STCW based competencies (Chauvin et al, 2013).

2.1.4 Future directions in MET

Different maritime competencies and skills become required as shipping operations continue to evolve. It is predicted that required maritime skills will be even more complicated as different types of ships such as manned, unmanned, shore-side control, semi-autonomous, fully autonomous etc. sail together at sea. This being the case, MET needs continual development and updating so that it can provide these changing skills that are highly technology and technically oriented. In this regard, different maritime actors such as maritime faculties, training centers, simulator and technology providers, and shipping companies need to work together in development and utilization of enhanced MET practices (Sharma et al, 2021).

To start with, maritime shore-based simulators has allowed cadets to practice and develop their seafaring skills regardless of time and without having to go onboard ship. Shore-based simulators enable trainers creating diverse realistic scenarios which would be too expensive and dangerous with real ships. In this regard, simulator-based training can be considered as a cost-effective and powerful means of maritime training (Hjelmervik et al, 2018). Succesful simulators improve learning and decrease errors (Salas et al, 2012). Three-dimensional (3D) visualization in simulators are very useful as it provides trainees with near real life experience (Cwilewicz and Tomczak, 2008). Moreover, simulator-based training enhances trainees' risk assessment and decision making in risky situations (Sanfilippo, 2017) and develops critical thinking through case-based learning (Bhardwaj and Pazaver, 2014).

As information technology develops, technology-enabled education and trainig solutions arise for maritime domain which is also the case for other domains. In this

regard, Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR) as well as wearable technologies create new education and training opportunities in maritime domain. These Technologies create authentic training environments for developing practical maritime competencies. Besides, such opportunities are more affordable and reachable compared to land-based simulators as they can be used on portable computers and mobile phones (Mallam et al, 2019).

Although these technologies are generating new exciting opportunities for MET, they should be well understood before their utilization with current practices. This means the possible advantages, disadvantages, possible trade-offs as well as strengths and weaknesses should be researched in a detailed way. Future research should also investigate which sort of technologies should be used in development of specific competencies (Mallam et al, 2019). To sum up, new technologies are expected to have an important role in the future of MET but they should be well understood so that we can use them wisely. In fact, this study aims to provide a research-based understanding about design, development, and utilization of serious gaming, which is also believed to be an important method in future MET practices.

2.2 Serious Game Design in Future Skills Development

2.2.1 Serious games

A game is a systematic play with rules, challenges, and goals created for entertainment (Fotiadis and Sigala, 2015). However, gamification is defined as the "use of game elements in non-game contexts" (Sellberg et. al, 2019), which means gamification has a serious purpose rather than pure entertainment (Morschheuser et al, 2017). Kapp (2013) explains gamification as using gaming feautures for engaging people and enhancing learning experiences. Similarly, serious games are games intended for a variety of serious purposes. Main difference between serious games and gamification is that serious games are in fact games while gamification employs game elements for purposes other than entertainment (Deterding, 2011).

The term "Serious Game" was first proposed in 1968 by Clark Abt (Abt, 1970) defining serious games and simulations 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). Similarly, serious games are explained as games generated for training and motivating players for enhanced learning practices (Djaouti et al., 2011).

Game elements increase the learning efficiency in various aspects. To start with, Bai et al. (2020) tell that game elements such as badges, points, and challenges enhance participation in learning. In addition, Gray et al. (2019) as well as Zainuddin et al. (2020) explain that gaming features increase engagement and motivation and thus promote higher-order learning. Serious games are also reported to be useful for attitude change (Chow et al, 2020), developing understanding and retention (Wang and Abbas, 2018), empowering critical thinking (Turner at al, 2018) and fostering goal setting (Yıldırım and Şen, 2019).

Serious gaming is becoming more popular in education. To start with, Koupritzioti and Xinogalos (2020) provided a serious game application for learning programming concepts. In addition, Lee (2020) created an Augmented Reality (AR)-based mobile serious game for foreign language learning. Moreover, Khan et al. (2022) utilized serious gaming perspective for enhancing cyber security education. Fokides (2018) also used a serious game for teaching Math to primary school students. He found out that the students who played the serious game mostly outperformed the ones who did not play it. Besides, Rodriguez (2022) statistically proved the efficiency of serious games on engineering education. Moreover, serious games provide realistic training opportunities for healthcare personnel and students with no risk of harm to anyone (Benkhedda and Bendella, 2019; Fusco et al, 2022; Haruna et al, 2019; Kapralos et al, 2015; Sardi et al, 2017; Teschner, 2016). In addition, business (Fotiadis and Sigala, 2015; Fu et al, 2016; Loon et al, 2015), language learning (Alyaz et al, 2017; Berns et al, 2011; Garrido-Inigo and Rodríguez-Moreno, 2015; Gonzalez- Pardo et al, 2014), sports (Hamari and Sjöblom, 2017), social learning for sustainable development (Tribaldos and Schneider, 2021), environmental protection (Nygren et al, 2022) and music (Margoudi et al, 2016) are among other fields where serious games are used.

Despite their increasing utilization, the literature still needs studies to enhance educational capability of serious games (Silva, 2020). More studies on effects of game elements on serious game design are also needed (Johnson et al, 2017). Similarly, it is explained that serious gaming studies commonly focus on the content to be taught (Laporte and Zaman, 2018) instead of the design and development efforts (Korhonen et al, 2017). Chan and Zary (2019) also explain that allocation of insufficient resources

is another difficulty standing in the way of design and development of effective serious games.

Looking critically at serious game literature, it has been determined that studies which provide practical and step-by-step guidance on design and development of serious games are needed. In fact, this study aims to fulfill this research gap for maritime domain by providing a methodology for facilitating easier design and development of maritime serious games.

2.2.2 Future skills development

Skill is defined as the "ability to do something in an effective manner" (Carmeli and Tishler, 2006, p.13). The term future skills mean the new set of skills which are necessary for everyone to be successful at working, learning, and living (Trilling and Fadel, 2009). The literature proposes various approaches for defining future skills. To start with, Redeker et al. (2012) grouped the future skills as personal skills, social skills, and learning skills where personal skills include responsibility, risk taking, resilience, creativity, and initiative. They further stated that social skills are networking, empathy, compassion, teamworking, and co-constructing while learning skills are organizing, managing, metacognitive skills, and failing forward. Voogt and Roblin (2012) offered communication, collaboration, ICT skills, social and cultural skills, creativity, critical thinking, problem solving, and productivity as most common future skills. Dede (2010) explained that future skills enables extracting the valuable data from the high amount of incoming data. Kickmeier- Rust and Dietrich (2012) told that future skills include non-linear thinking, problem solving, communication skills and creativity.

Digital learning environments foster future skills development through active and personal learning practices (Cooke et al, 2014; Dalal and Akdere, 2018; OECD, 2019). Design flexibility is a key feauture for digital learning environments which are to include the learners in the design process in order to provide them with a more personalized learning path (Garavan et al, 2012; Salinas and De-Benito, 2020; Sonnenberg et al, 2014).

Serious games can also be utilized for supporting the future skills development (Qian and Clark, 2016; Romero et al, 2015). However, serious games are generally created with a focus on the curriculum itself rather than the competencies to be developed. In

this regard, development of the future skills should be the priority during the design of serious games for increasing their effectiveness (Romero et al, 2015).

2.2.3 Serious game design approaches in future skills development

In this study, a systematic literature review about serious game design approach is conducted with a special focus on future skills development. The review is accomplished in accordance with the guidelines provided by Kitchenham (2004) and Kitchenham and Charters (2007). Three stages of a systematic literature review, which are also applied in this study are “the Planning Stage”, “the Conducting Stage” and “the Reporting Stage”, each of which are shown in different rows of Figure 2.1.

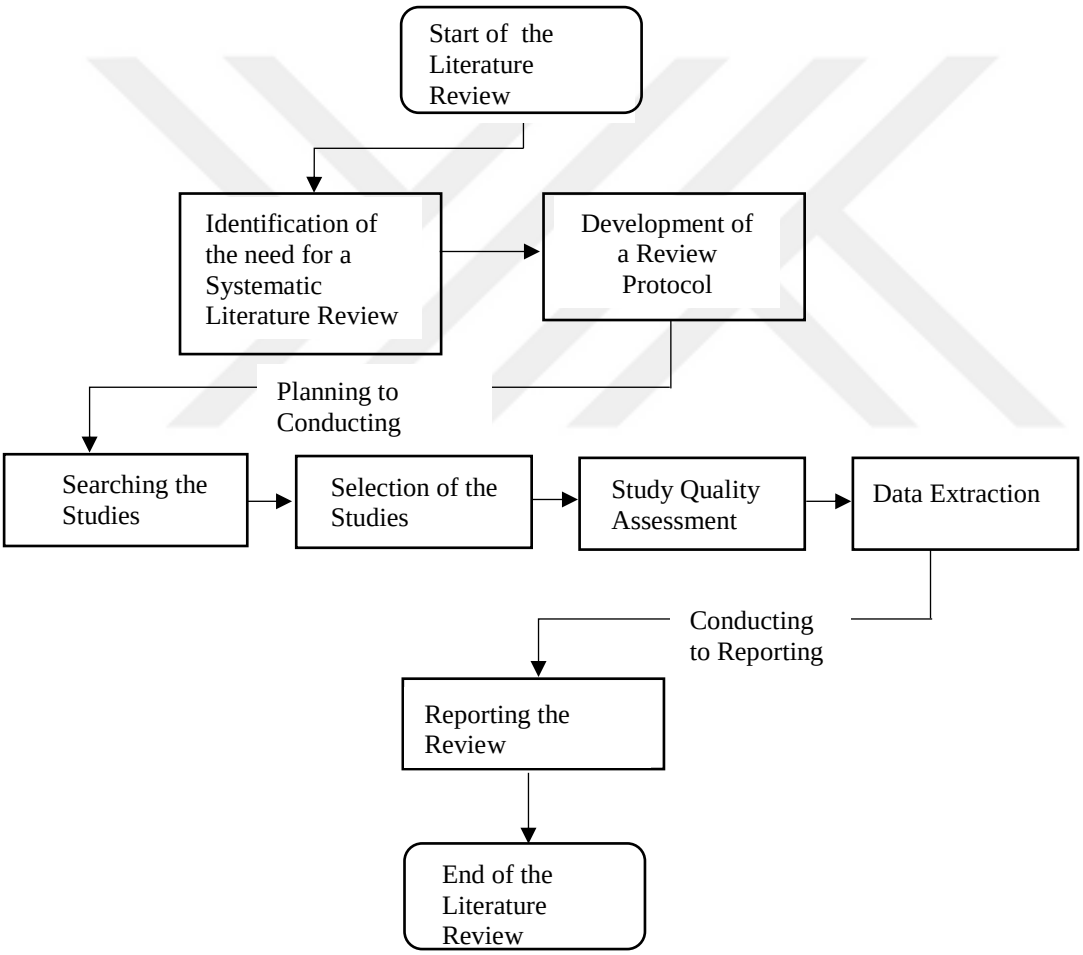

Figure 2.1: Steps of the systematic literature review procedure.

2.2.3.1 Planning phase

In this phase, the purpose of the review and the reason why it is needed are decided. Serious game studies mostly deal with particular serious game applications instead of serious game design for future skills development (Qian and Clark, 2016; Romero et

al, 2015). Serious games should focus on future skills development and this approach should be taken throughout the design process (Romero et al, 2015). In this regard, current study focuses on serious game design approaches with a particular emphasis on the development of future skills.

After that, a review protocol with the search procedures is generated. These procedures include the research questions, search strategy, inclusion, exclusion and quality assessment criteria as well as the data to obtain from the selected studies.

Research questions (RQs), which are the questions to be answered so that the review achieves its intended purpose, are the first elements of the protocol. The questions that the review tries to answer are:

1. What are the approaches (models, methods/methodologies, and frameworks) used for serious game design?

2. Which future skills are explicitly supported by the identified serious game design approaches?

3. Which learning theories/aspects are adopted by the identified serious game design approaches to support the development of future skills?

4. What are the game design elements implemented in the identified serious game design approaches to support the development of future skills?

Following the development of the questions to answer, the search strategy is defined. This study conducted automated searches in February 2022 on the digital libraries of Science Direct, Web of Science, Scopus, and ProQuest. The titles, abstracts and keywords of Articles, books, book chapters, conference proceedings and master theses and doctoral dissertations published between 1975 and 2022 are searched. Backward snowball method is also applied which requires reviewing the references of the studies for finding additional studies (Wohlin, 2014) for enhancing the search results.

Inclusion and exclusion criteria are then to be decided for developing the review protocol. 2 inclusion criteria are 3 exclusion criteria are identified for the purpose of this study. The inclusion criteria are being published between 1975 and 2022 and mentioning about a serious game design approach. The first exclusion criterion is not proposing a serious game design approach with specific steps of serious game design.

The second exclusion criterion is being written in a language other than English. The third exclusion criterion is the unavailability of the study as full text.

The quality assessment criteria are the defined as the final step of the review protocol and thus the planning phase of the systematic literature review. Clearly explaining the adopted methodology and presenting the used data are defined as the quality assessment criteria of this review. In this regard, the studies passing the inclusion and exclusion criteria are evaluated against these quality assessment criteria to be included as final studies.

2.2.3.2 Conducting phase

In this phase, two searches are firstly accomplished within the scope of the inclusion criteria. Search-1 finds 7084 studies about serious game. These studies are narrowed down to 2466 about serious game design approaches in Search-2. The keywords employed in the searches are shown in Figure 2.2.

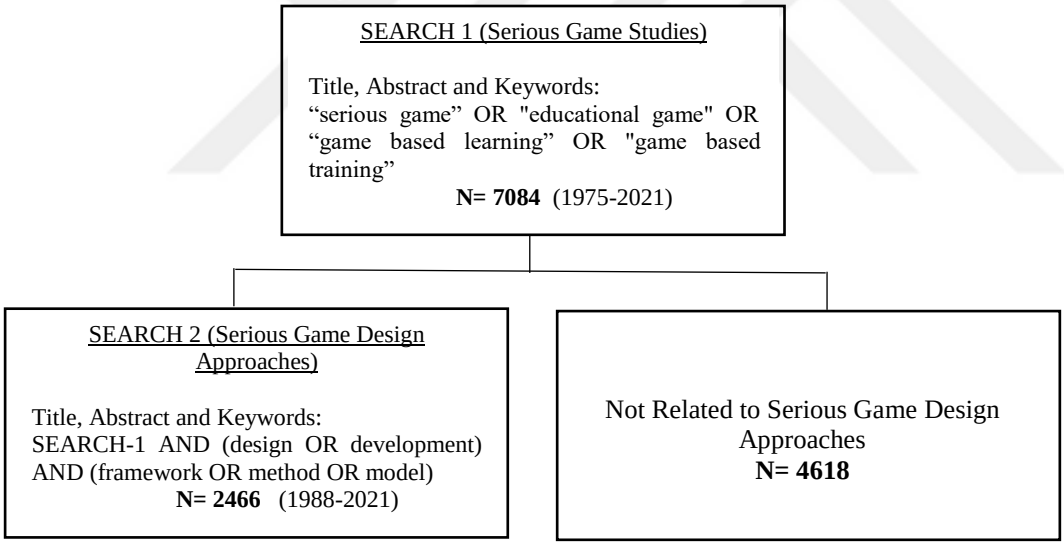

Figure 2.2: The keywords used in the searches on digital libraries.

For applying the second inclusion criterion, titles and abstracts of 2466 studies are checked. 455 studies which either explains or proposes a seious game design approach passed this inclusion criterion. Out of 455 studies, 16 (4%) studies passed the first exclusion criterion, 13 of which also passed the second and third exclusion criteria and are chosen for quality assessment. Besides, 64 studies from backward snowball method passed the inclusion criteria. 43 (67%) of these studies are excluded by the

first exclusion criterion and 2 of them could not pass the second and third exclusion criteria, leaving 19 (30%) studies chosen for quality assessment.

Finally, all of the 32 studies which are chosen for quality assessment (13 from searches and 19 from backward snowball method) passed the defined criteria and regarded as final studies. This means these 32 studies are qualified for data extraction and thus being reported. The process of determining the final studies is summarized in Figure 2.3.

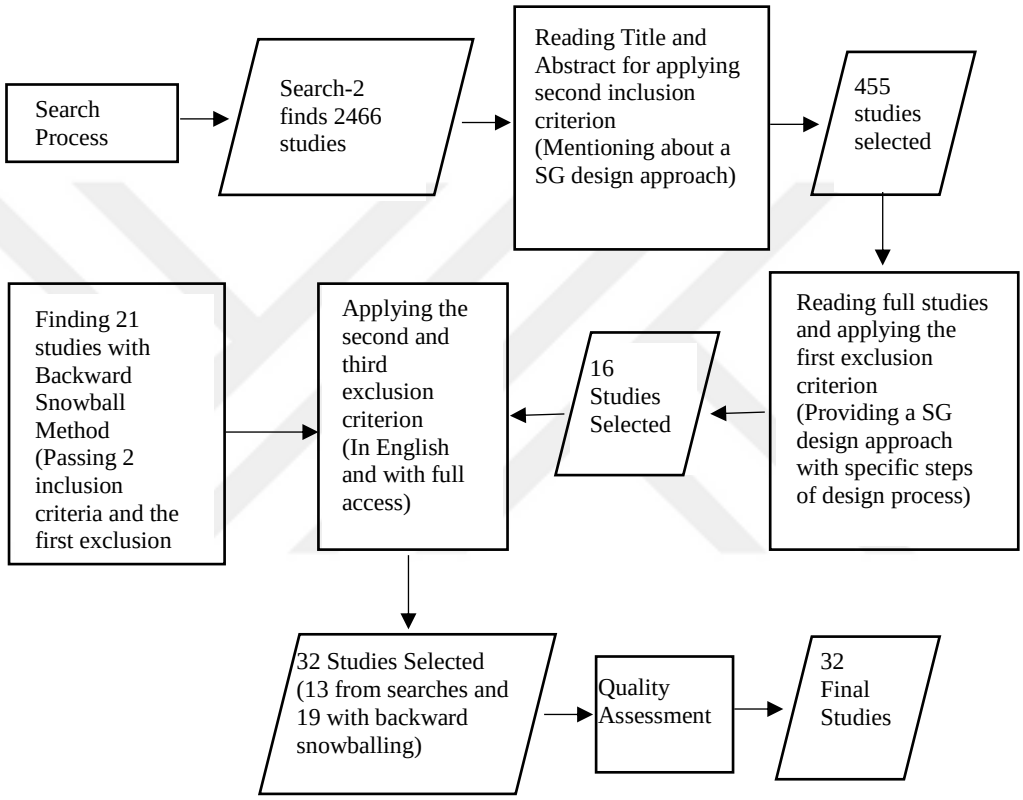

Figure 2.3: The steps to find final number of studies.

2.2.3.3 Reporting phase

Final 32 studies are reported to answer the research questions of the review. To start with, Figure 2.4 and Figure 2.5 show the years and countries of the final studies respectively.

Figure 2.4 shows that the studies date back to 2002, 18 (56%) of them being published in the last decade pointing out the increasing popularity of the serious game design approaches. Additionally, Figure 2.5 depicts that 8 (25%) studies have been conducted in USA and 3 (9%) studies in England and Spain. 4 RQs are answered below for

providing an understanding of serious game design approaches in developing future skills.

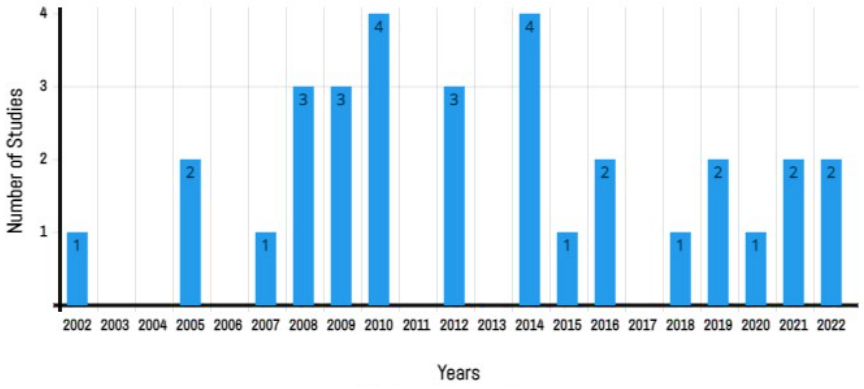

Figure 2.4: Years of the final 32 studies.

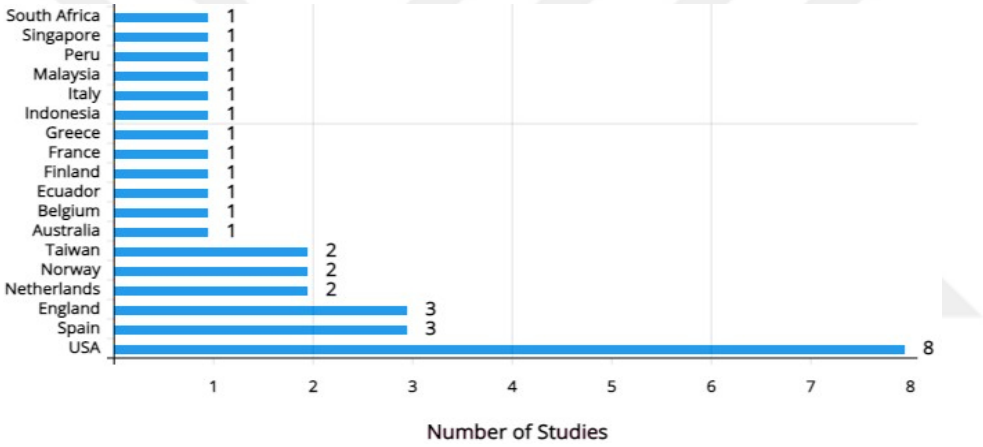

Figure 2.5: Countries of the final 32 studies.

2.2.3.4 Final serious game design approaches

This chapter responses to the first research question entitled "What are the approaches used for serious game design?". 32 approaches identified for focusing serious game design include 14 framework, 12 model, and 5 method/methodology, while 1 study (Torrente et al, 2013) has not elaborated on the type of the approach. 22 (69%) approaches are proposed for education, 5 (16%) approach are proposed for healthcare, and 2 (6%) approach are developed for the military. Other three approaches are offered for education in tourism (Winn, 2009), decision making (Daylamani-Zad et al, 2016), and cyber security (Katsantonis et al, 2019).

It is also found out that 18 (56%) of the design approaches do not propose specific game design steps while 14 approaches lack some elements (assessment, scenarios, game design elements etc.) of game design.

Gamification and serious games have behavioral, learning (cognitive) and motivational outcomes (Carenys and Moya, 2016; Krath et al, 2021; Lamb et al, 2018). In this study, 32 design approaches are classified into these 3 groups according to their intended outcome. The classification is explained below.

2.2.3.4.1 Design approaches for behavioral outcomes

Serious games are commonly utilized for enhancing the behavioral outcomes. Social collaboration and teamwork (Kordaki and Gousiou, 2017; Vlachopoulos and Makri, 2017), engagement and participation (Ekici, 2021; Jarnac de Freitas and Mira da Silva, 2023) and attitude change (Chow et al, 2020), and are among these behavioral outcomes. 4 design approaches targeting behavioral outcomes are explained in Table 2.1.

Table 2.1: Summary of the design approaches for behavioral outcomes.

Study	Name of the Approach	Target Domain	Steps for SG Design	Strengths and Weaknesses
Lavieri, 2014	Adaptive Learning Game Design (ALGAE) Model	Education	-Learner -Action -Conflict Cooperation -Game Engine -Instructional Strategies	S: Facilitate improved learning outcomes, non-exclusive applicability, and link between educators and game designers. W: Game design steps are not specific enough to provide concrete guidance for serious game design.
Daylamani, Zad et al, 2016	Lu-Lu Framework	Education and Training (Decision Making)	-Player Profiling -Team Profiling -Characterization Scoring -Decision Making -Leveling	S: Uses behavior driven development approach which enables successful integration of all the key ingredients of the framework. W: Fails to concretely guide the designer about assessment design
Pouls et al, 2022	Intervention Mapping Framework	Healthcare	-Exploring Problem -Defining Objectives -Selecting Behavior Change Technique -Intervention Design -Implementation -Evaluation	S: Provides task and methods for each step that leads to a product that guides the subsequent step. W: Fails to concretely guide the designer about serious game design
Yildirim, 2010	N/A (Framework)	Military	-Previous Cases -Case-based Reasoning -Military Knowledge	S: Combines the aspects of military simulation systems and game technology, as well as social and cultural aspects. W: Game design steps are not specific enough to guide serious game design

Firstly, “Adaptive Learning Game Design (ALGAE)” model (Lavieri, 2014), focusing on adaptiveness, intends to guide the design of engaging educational serious games. Additionally, Intervention Mapping Framework (Pouls et al., 2022) aims to enable

serious game design by “defining change objectives” and “selecting behavior change technique” steps.

2.2.3.4.2 Design approaches for learning outcomes

Cognition is the ability to understand by reasoning and problem-solving (Lamb et al, 2018). Serious games offer learning (cognitive) outcomes such as critical thinking (Qian and Clark, 2016; Turner at al, 2018), understanding and retention (Braghirolli et al, 2016; Wang and Abbas, 2018), knowledge acquisition (Vlachopoulos and Makri, 2017) and perceptual skills (Lamb et al, 2018).

12 of the identified 32 approaches, shown in Table 2.2, intents to provide learning outcomes. For instance, pedagogical objective step of the “iPlus” methodology (Carrion-Toro et al., 2022) emphasizes the educational function of serious games. Moreover, Four Dimensional Framework (De Freitas and Jarvis, 2009) has a pedagogy step for providing learning outcomes.

Table 2.2: Summary of the design approaches for learning outcomes.

Study	Name of the Approach	Target Domain SG	Steps for Design	Strength and Weakness
Kirkley et al, 2005	Simulation Game Instructional System Design Model (SG-ISD)	Education	-Analysis -Concept -Design -Questions and Answers	S: Embedded in a prototype authoring environment W: Fails to concretely guide the designer about creating game scenarios, assessment design, and which game design elements to use
De Freitas and Jarvis, 2009	Four Dimensional Framework (4DF)	Healthcare	-Learner Specifics -Pedagogy -Representation -Context	S: Includes context, representation, pedagogy, and learner as part of the design process W: Game design steps are not specific enough to provide concrete guidance for serious game design
Ibrahim and Jaafar 2009	Educational Games Design Model	Education	-Game Design -Pedagogy -Learner Content Modelling	S: Designed specifically for student's self- learning with an integrated self- assessment modules W: Game design steps are not specific enough to provide concrete guidance for serious game design
Schottman et al, 2010	7-Step Method	Education	-Specification of Pedagogical Objectives -Choosing SG Model -Description of the Scenario -Software Components -Detailed Scenario -Pedagogical Quality Control -Specifications for Contractors	S: Helps different actors collaborate in an efficient way especially for creating the scenarios of the serious game W: Fails to concretely guide the designer about creating game scenarios, assessment design, and which game design elements to use

Table 2.2 (continues): Summary of the design approaches for learning outcomes.

Study	Name of the Approach	Target Domain	Steps for SG Design	Strength and Weakness
Abeele et al, 2012	P III Framework	Education	-Concept Design -Game Design -Game Development	S: Proposes an iterative and incremental process which enables player-centered design W: Game design steps are not specific enough to provide concrete guidance for serious game design
Mitgutsch and Alvarado, 2012	Serious Game Design Assessment (SGDA) Framework	Healthcare	-Purpose -Content -Fiction -Mechanic -Aesthetic -Framing -Game System	S: A constructive framework for serious game design, assessment, evaluation, criticism and prototyping with a purposeful-by-design perspective W: Game design steps are not specific enough to provide concrete guidance for serious game design
Jeuring et al, 2014	5/10 Method	Education (Engineering)	-Design Learning Task -Sequence Task Classes -Set Performance Objectives -Design Supportive/ Procedural Information -Design Challenges/Levels	S: Provides guidelines for designing clearly defined learning goals and objectives with a connection to the existing curriculum W: Fails to concretely guide the designer about assessment design and which game design elements to use
Yust, 2014	N/A (Framework)	Education (Social Science)	-Decomposition of Knowledge -Arrange Ideas into Knowledge Hierarchy -Identify Branches/Tiers -Convert Knowledge into Mechanics and Structures -Explore Design Space -Adapt Art, Aesthetics etc.	S: Critically analyzes domain of knowledge and derives a knowledge hierarchy which aligns well with gameplay, art, story, and sound. W: Fails to concretely guide the designer about assessment design

Table 2.2 (continues): Summary of the design approaches for learning outcomes.

Study	Name of the Approach	Target Domain	Steps for SG Design	Strength and Weakness
Carvalho et al, 2015	Activity Theory Model of Serious Games (ATMSG)	Education (Engineering)	-Identify Activities -Represent Game Sequence -Identify Actions, Tools and Objects -Describe Implementations	S: Depicts how game elements connect to each other and contribute to the desired learning goal W: The model does not provide enough guidance about scenario and assessment design
Katsantonis et al, 2019	Conceptual Framework for E-Learning and Training (COFELET)	Education and Training (Cyber Security)	-Select the Mission -Realize Game Conditions -Create a Scenario Execution Flow -Present new Knowledge, Skill, Ability Related Content -Perform Task and Present Hint -Perform Assessment -Provide Feedback and Rewards	S: Models multiple aspects of the game, includes multiple adaptability features, and applies efficient assessment and reward schemes. W: Fails to concretely guide the designer about assessment design and which game design elements to use
Carrion-Toro et al, 2020	iPlus Methodology (Engineering &Social Science)	Education	-Identification -Pedagogical Objectives -Ludic Game Script -Gameplay -Refine	S: Utilizes a flexible, participatory, and user centered approach W: Game design steps are not specific enough to provide concrete guidance for serious game design
Roedavan et al, 2021	N/A (Model)	Education	-Education Content Ideation -Tech and Art Development -Learning Mechanics -Assessment Mechanics -Prototype -Testing and Validation	S: Includes affective, motivation, cognitive, and social aspects of serious games W: Fails to concretely guide the designer about the game design elements to use

2.2.3.4.3 Design approaches for motivational outcomes

Increased motivation leads to better educational outcomes (Ryan and Deci, 2000). Serious games increase enjoyment (Ab Jalil et al, 2020; Kordaki and Gousiou, 2017), satisfaction (Boyle et al, 2016), immersion (Connolly et al, 2012), positive attitudes towards the game (Vlachopoulos and Makri, 2017), and flow (Koivisto and Hamari, 2019) in a way to provide enhanced motivational outcomes.

2 of the final approaches, included in Table 2.3, focus on positive motivational outcomes. Firstly, the methodology proposed by De Lope et al. (2021) targets increased enjoyment and immersion by focusing on the adventure feature of serious games. Secondly, Educational Game Development Approach (EDGA) (Torrente et al, 2013) highlightes increased motivation, immersion, and flow of the players for designing authentic environments for the healthcare domain.

Table 2.3: Summary of the design approaches for motivational outcomes.

Study	Name of the Approach	Target Domain	Steps for SG Design	Strength and Weakness
De Lope et al, 2021	N/A (Methodology)	Education	-Design of Acts -Design of Scenes -Design of Scenarios -Design of Characters and Objects -Adaptation Design -Design of Educational Challenges -Design of Actions -Design of Dialogues	S: Offers a graphical approach represents serious games in a structural form. W: Fails to concretely guide the designer about assessment design and which game design elements to use
Torrente et al, 2014	Educational Game Development Approach (EDGA)	Healthcare	-Analysis -Design -Implementation -Quality Assurance	S:Focuses on cost effectiveness learning efficiency and student acceptance W: Fails to concretely guide about assessment design

2.2.3.4.4 Design approaches for multiple outcomes

14 of the final approaches depicted in table 2.4 target more than one of these 3 types of outcomes. To start with, Document Oriented Design and Development for Experiential Learning (DOODLE) model (Mcmahon, 2009) intends to improve the learning and motivational outcomes by enhancing learning approach, immersion and flow. I's Have It framework (Annetta, 2010) facilitates learning, behavioral, and motivational outcomes through the informed teaching, interactivity, and immersion steps respectively. Breien and Wasson (2022) propose eLuna framework that supports all of the 3 types of outcomes by focusing on motivation, engagement, and learning. Similarly, the Narrative-based Contextual Game for Language Learning (NCGLL) framework proposed by Chen et al. (2018) stress the behavioral outcome with the storyline design step and cognitive outcomes with the storyline design step.

Table 2.4: Summary of the design approaches for multiple target outcomes.

Study	Name of the Approach	Target Domain	Target Outcome	Steps for SG Design	Strength and Weakness
Garris et al, 2002	Input Process Output Model	Military	Learning, Behavioral	-Instructional Content -Game Characteristics -User Judgment -User Behavior -System Feedback -Learning Outcomes	S: Offering a cycle which pairs instructional content with appropriate game features W: Game design steps are not specific enough to provide concrete guidance for serious game design
Kiili, 2005	Experiential Gaming Model	Education	Learning, Motivational	-Idea Generation -Challenges -Active Experimentation -Reflective Observation -Schema Construction	S: Describing learning as a cyclic process W: Fails to concretely guide the designer about creating game scenarios, assessment design, and which game design elements to use
Amory, 2007	Game Object Model II (GOM II)	Education	Learning, Behavioral	-Game Space -Visualization Space -Elements Space -Computer Mediated Communication -Social Space	S: Provides a wider variety of abstract and concrete interfaces to support serious game design W: Game design steps are not specific enough to provide concrete guidance for serious game design
Fu and Yu, 2008	3 Layered Thinking Model	Education	Learning, Motivational	-Pedagogical Level -Design Level -Achievement Level	S: Integrates game goals within the curriculum and game design W: Game design steps are not specific enough to provide concrete guidance for serious game design

Table 2.4 (continues): Summary of the design approaches for multiple target outcomes.

Study	Name of the Approach	Target Domain	Target Outcome	Steps for SG Design	Strength and Weakness
Gunter et al, 2008	RETAIN Model	Healthcare (Pharmacy)	Learning, Behavioral, Motivational	-Relevance -Embedding -Transfer -Adaptation -Immersion -Naturalization	S: Effectively combines game theory, instructional design and educational learning W: Game design steps are not specific enough to provide concrete guidance for serious game design
Winn, 2009	Design, Play, Experience Framework	Business and Management (Tourism)	Learning, Behavioral	-Set Goals -Design, Play, Experience -Check Goals	S: Provides a common language for serious game design and a methodology to analyze a design W: Game design steps are not specific enough to provide concrete guidance for serious game design
Mcmahon, 2009	Document Oriented Design and Development for Experiential Learning (DODDLE) Model	Education (Social Science)	Learning, Motivational	-Situation Analysis -Design Proposal -Design Documentation -Production Documentation -Development -Evaluation -Implementation	S: Provides a heuristic for documentation that supports the development of creative and innovative games while enabling communication between key stakeholders W: Game design steps are not specific enough to provide concrete guidance for serious game design
Annetta, 2010	I's Have It Framework	Education	Learning, Behavioral, Motivational	-Identity -Immersion -Interactivity -Increasing Complexity -Informed Teaching -Instructional Design	S: Grounded in research on education and psychology along with instructional technology and learnings science W: Game design steps are not specific enough to provide concrete guidance for serious game design

Table 2.4 (continues): Summary of the design approaches for multiple target outcomes.

Study	Name of the Approach	Target Domain	Target Outcome	Steps for SG Design	Strength and Weakness
Voogt and Roblin, 2012	N/A (Framework)	Education	Learning, Motivational	-Intended Learning Outcomes -Game Attributes -Learning Activity -Reflection -Games Genre -Game Mechanics -Game Achievement	S: Identifies 12 necessary serious game attributes and links them with behavioral intention to use W: Game design steps are not specific enough to provide concrete guidance for serious game design
Chamberlin et al, 2012	Learning Games Design Model	Education	Learning, Motivational	-Refine Objectives -Brainstorm and Define Anticipated Product -Prepare Design Document -Create Prototype -Design -Evaluation, Dissemination	S: Outcome based design process which is constantly modified according to what learners need to know W: Fails to concretely guide the designer about creating game scenarios, assessment design, and which game design elements to use
De Lope et al, 2017	N/A (Methodology)	Education	Learning, Behavioral	-Chapters Design -Scenes Design -Development of Educational Challenges and Assessment -Identification of Emotions -Adaptation Design -Collaboration Design	S: Based on an interactive narrative that integrates game aspects and manages visual representation of the game design W: Fails to concretely guide the designer about assessment design
Chen et al, 2018	Narrative-based Contextual Game for Language Learning Framework	Education	Learning, Behavioral	-Storyline Design -Character Design -Quest Design	S: Organizes storyline, character, and quest for SG design W: Game design steps are not specific enough to provide concrete guidance for serious game design

Table 2.4 (continues): Summary of the design approaches for multiple target outcomes.

Study	Name of the Approach	Target Domain	Target Outcome	Steps for SG Design	Strength and Weakness
Avila-Pesantes et al, 2019	N/A (Model)	Education (Social Sciences)	Learning, Motivational	-Analysis -Design -Development -Evaluation	S: Aims to facilitate interactive learning, which incorporates game design document and software development life cycle W: Fails to concretely guide the designer about assessment design
Breien and Wasson, 2022	eLuna Framework	Education	Learning, Behavioral, Motivational	-Preparation -Co-Design -Co-Specification -Development	S: Proposes a visual language to support the co-design and co-specification as a blueprint W: Fails to concretely guide the designer about serious game design

2.2.3.5 Future skills identification

The second RQ entitled “Which future skills are explicitly supported by the identified serious game design approaches?” is concerned in this section. In this regard, final approaches are studied with a focus on the future skills they support. 11 of the future skills in Assessment and Teaching of 21st Century Skills framework (Binkley et al, 2012) and Framework for 21st Century Learning (P21, 2019) are selected as future skills. These skills are creativity and innovation, critical thinking, problem solving, learning to learn, communication, collaboration (teamwork), ICT literacy, flexibility and adaptability, initiative and self-direction, social skills and productivity. Table 2.5 shows the studies that support these future skills.

Table 2.5 Serious game design approaches that support future skills.

Future Skills	Supporting Studies
Creativity and innovation	-
Critical thinking	Daylamani-Zad et al, 2016; Torrente et al, 2014
Problem solving	Daylamani-Zad et al, 2016; Torrente et al, 2014; Gunter et al, 2008; Ibrahim and Jaafar, 2009
Learning to learn	-
Communication	Annetta, 2010; Chen et al, 2018; Lavieri, 2014
Collaboration and teamwork	Annetta, 2010; Daylamani-Zad et al, 2016; De Lope et al, 2017; Lavieri, 2014
ICT literacy	-
Flexibility and adaptability	-
Initiative and self-direction	-
Social skills	Chen et al, 2018; Lavieri, 2014
Productivity	-

It is found that 5 of the 11 future skills are supported by 8 different serious game design approaches. Problem solving and collaboration and teamwork, supported by 4 studies, are the skills that are supported by most studies. Communication is supported by 3 approaches while 2 approaches support social skills. Chen et al. (2018) guide development of interactions with non-player characters of the game in a way to support communication and social skills. Lavieri (2014) intends to develop communication, collaboration and teamwork, and social skills of the players by supporting interaction, communication, in-game dialogues and collaboration. In addition, the interactivity feature of the I’s Have It Framework (Annetta, 2010) fosters communication and teamworking. De Lope et al. (2017) aims to support collaboration skills of the players by the collaboration design step of the methodology. Through the adjustment zone in the Lu-Lu framework Daylamani-Zad et al. (2016) also intents to improve

collaboration skills of the players by making them discuss their decisions to find the right decision.

Torrente et al. (2014) proposed a decision-making element in Step-2 of the EDGA model for fostering critical thinking and problem solving skills. They recommended creating realistic scenarios and making players find solutions to the problems in the scenarios. Amory (2007) proposes visualization space of the GOM-II model for supporting critical thinking skills. Transfer element of the Retain serious game design model (Gunter et al, 2008) and pedagogy factor of Educational Games Design Model (Ibrahim and Jaafar, 2009) propose scenario-based problem solving for developing problem solving skills of the players.

2.2.3.6 Learning theories perspective

In this section, RQ-3 (Which learning theories are adopted by the identified serious game design approaches to support the development of future skills?) is considered. It is stated that serious game design studies can not always adopt correct learning theories (Li and Tsai, 2013) despite the importance of achieving this (Young et al, 2012). In fact, Wu et al. (2012) explained that most of the serious game design studies do not adopt any learning theory at all. Table 2.6 explains the learning theories utilized by the serious game design approaches that support 5 future skills, as identified in Section 2.2.3.5.

Table 2.6: Learning theories adopted for supporting future skills.

Supported Future Skill	Study	Learning Theory	Purpose
Critical thinking	Torrente et al, 2014	-Problem based learning -Active learning	Creating scenario based decision making environments
	Daylamani-Zad et al, 2016	-Experiential learning -Active learning -Constructivist learning	Creating decision making opportunities for actively constructing critical thinking.
Problem solving	Torrente et al, 2014	-Scenario-based learning -Active learning	Creating scenario based opportunities for developing problem solving
	Daylamani-Zad et al, 2016	-Experiential learning -Active learning - Problem-based learning - Constructivist learning	Creating decision making experiences for actively constructing problem solving skills

Table 2.6 (continues): Learning theories adopted for supporting future skills.

Supported Future Skill	Study	Learning Theory	Purpose
	Gunter et al, 2008	-Active learning -Experiential learning	Making learning an active process where learners construct new ideas upon previous knowledge in realistic conditions
	Ibrahim and Jaafar, 2009	-Active learning -Problem-based learning	Designing active learning opportunities for building problem solving skills
Communication	Chen et al, 2018	-Social learning	Using dialogues with non-player characters and this way supports communication skills
	Annetta, 2010 Lavieri, 2014	-Social learning	Developing communication skills by building interaction with other players
Collaboration and Teamwork	Lavieri, 2014	-Social learning -Experiential learning	Player learns by working together with other players thus develops collaboration and teamwork skills
	Annetta, 2010	-Social learning -Experiential learning -Problem based learning	Allowing players construct knowledge through interactions in multiplayer game design
	Daylamani-Zad et al, 2016	-Social learning -Constructivist learning	Making the players work together as a team for group decisions
	De Lope et al, 2017	-Problem based learning -Social learning	Working together as a group to eliminate the challenges
Social skills	Chen et al, 2018 Lavieri, 2014	-Social learning	Providing socially constructed knowledge through interaction in a way to support their social skills

Problem-based learning and social learning, adopted by 5 approaches, are the most popular learning theories among the final studies. Problem-based learning proposes that experimentation and problem solving are key to effective learning (Dabbagh and Dass, 2013). According to social learning theory, learning takes place by observation from and interaction with the environment (Bandura, 1971). Social learning is useful

for serious game design as it creates social observation opportunities (Jeen et al, 2007) and role model game characters (Fuchslocher, 2011).

Active learning and experiential learning perspectives are used in 4 of the final approaches. Active learning fosters self-regulated learning (Bell and Kozlowski, 2008), improves learner engagement, and problem solving (Edens, 2000). In addition, experiential learning, built on constructivist learning theory (Kolb, 2013a), explains that knowledge is obtained, rather than passively learned by instruction, through personal and environmental experiences on the sequence of concrete experience, reflective observation, abstract conceptualization and active experimentation (Kolb, 2013a).

2.2.3.7 Game design element implementation

This section concerns the RQ-4 (What are the game design elements implemented in the serious game design approaches to support the development of future skills?). It is explained that serious games should use design elements such as adaptive challenge, curiosity, self-expression, discovery, clear goals, clear rules, player control, immersion, collaboration, competition, immediate feedback, variable rewards, which are also used by the games created for entertainment (Anderson, 2011; Squire, 2011). Vos et al. (2011) utilized interactivity, role playing, collaboration and competition as serious game design elements. For the purpose of this study, before mentioned 14 game design elements are studied to identify the ones that are utilized in 8 serious game design approaches founded in this study to support future skills. Table 2.7 depicts the game design elements which are implemented for this purpose.

Table 2.7: Game design elements used for supporting future skills.

Game Design Element	Implementing Studies	Number of Studies
Adaptive Challenge	Annetta, 2010; Chen et al, 2018; De Lope et al, 2021; Gunter et al, 2008	4
Curiosity	Annetta, 2010; Chen et al, 2018; Gunter et al, 2008	3
Self-expression	-	-
Discovery	Chen et al, 2018	1
Clear goals	Chen et al, 2018; Daylamani-Zad et al, 2016; De Lope et al, 2017; Gunter et al, 2008; Ibrahim and Jaafar, 2009; Lavieri, 2014	6
Clear rules	Annetta, 2010; De Lope et al, 2017; Lavieri, 2014; Torrente et al, 2014	4
Player control	Annetta, 2010; Torrente et al, 2014	2
Immersion	Annetta, 2010; Chen et al, 2018; Gunter et al, 2008; Torrente et al, 2014	4

Table 2.7 (continues): Game design elements used for supporting future skills.

Game Design Element	Implementing Studies	Number of Studies
Collaboration	Daylamani-Zad et al, 2016; De Lope et al, 2017; Lavieri, 2014	3
Competition	Torrente et al, 2014	1
Immediate feedback	Annetta, 2010; Lavieri, 2014;Torrente et al, 2014	3
Variable rewards	Annetta, 2010; Gunter et al, 2008; Lavieri, 2014	3
Role playing	-	-
Interactivity	Annetta, 2010; De Lope et al, 2017; Gunter et al, 2008; Ibrahim and Jaafar, 2009; Lavieri, 2014	5

It is found that defining clear goals, used in 6 (75%) of the 8 design approaches, is the most commonly utilized game element. Games need to have specific goals in order to motivate players based on the goal-setting theory (Locke, 1968). Clear goals also support the flow experience (Csikszentmihalyi and Csikszentmihalyi, 1992) which fosters motivation according to the self-determination theory (Ryan and Deci, 2000). Interactivity in serious games also enhances learning practices by facilitating active learning (Chen et al, 2018). Interactivity, adaptive challenge, clear rules, and immersion are utilized in 5 (63%), 4 (50%), 4 (50%) and 4 (50%) of the 8 serious game design approaches. Annetta (2010) explain that the challenges should be in alignment with the skill levels of the players for enhancing the flow and thus effectiveness of the game. Serious games should also have clear rules for increasing their educational capability (Susi et al, 2007). Immersion is also key to the motivation, flow, and engagement of the player and thus an important element for serious game based learning experiences (Annetta, 2010). 3 (38%) of the analyzed approaches implemented collaboration, variable rewards, curiosity, immediate feedback elements in serious gaming practices.

2.3 Maritime Serious Gaming

2.3.1 Maritime serious gaming research

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, 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 about the game.

With regard to STCW-based competencies, Bruzzone et al. (2013) also created a serious game for familiarization of the crew to operating procedures onboard ships. In addition, Sartini (2020) used serious gaming approach for improving maritime english speaking skills of cadets and put forward that the game in fact enhanced their skills. Lastly, Türkistanlı and Kuleyin (2022) designed and applied a serious game for enhancing decision-making skills of maritime students in collusion prevention situations. They concluded that the game-based training supported students developing their decision-making skills.

The maritime literature also has serious game applications for providing knowledge outside the scope of STCW requirements. Firstly, Philbin-Briscoe et al. (2017) introduced "The Seafarers-1" serious game for teaching seaborne trade mechanisms and seafaring practices in the eastern Mediterranean during the Classical and Hellenistic periods, as a part of the European Union (EU)-funded "iMareCulture" Project. Within the scope of the same project, Poullis et al. (2019) proposed the "The Seafarers-2" game as the second prototype of the game introduced by Philbin-Briscoe et al. (2017). This game also aimed to provide engagement in learning about maritime cultural heritage, seafaring and trading in the Mediterranean Sea in the classical period.

In terms of maritime education outside the scope of STCW, Veronica and Calvano (2020) also presented a serious game for enhancing children's awareness of the ocean literacy and biodiversity as well as caring for life in the oceans. Steenbeek et al. (2020) combined ecosystem modelling and serious gaming approaches for providing perception of maritime spatial planning. Finally, Pruyn (2023) proposed a framework for analysing the use of serious games in academic maritime education and conducted two case studies for validation of the framework. The purpose of the first case study was teaching the students the link between maritime economics and technology while the second case study intended to provide insight into ship production activities.

Looking critically at the maritime literature, it is discovered that most serious games dealing with the STCW-based competencies intent to develop hard skills. In this regard, it is believed that more research is needed for education and training of soft skills. It is also concluded that studies providing comprehensive and adaptable methodologies about design and development of maritime serious games are needed for their effective utilization in the maritime domain.

2.3.2 Maritime serious gaming entrepreneurship ecosystem

This section presents information about examples of commercially available maritime serious games as well as the companies which provide them. For this purpose, an analysis of the maritime serious gaming entrepreneurship ecosystem is conducted and 6 companies providing commercially available maritime serious games are discovered. It should be stated that the discovered companies are the ones that are highly visible in the market, which means there might also be other companies that are not included in this study. Table 2.8 presents information about these companies and the serious games they provide.

Table 2.8: Information about maritime serious game providers.

Company	Location	Year	Number of SGs on Hard Skills	Number of SGs on Soft Skills	Utilized Technology	Domain of Products
A	USA	2020	<10	N/A	2D, 3D	Maritime
B	Türkiye	2011	<10	N/A	VR Simulation	Maritime
C	Greece	2006	4	N/A	VR Simulation	Maritime
D	Holland	2002	<10	N/A	VR Simulation	Maritime Safety Training
E	Türkiye	2011	9	N/A	3D, VR Simulation	Maritime
F	USA	2000	4	N/A	3D, VR Simulation	Maritime Other Trainings

To start with, it is found out that the number of companies providing maritime serious game is limited. 2 (Company-D and Company-F) out of 6 companies offer serious games also for other domains while 4 companies (Company A, Company-B, Company-C, and Company-E) are specialized only in maritime domain. In fact, all (6) companies provide not only serious games but also other kinds of online maritime trainings such as video-based trainings and simulations. Each of these companies provide less than 10 maritime serious games, which also makes the total number of games limited.

The foundation of these companies dates back to the year 2000 while it is discovered that all games have been developed in the last decade. In spite of the increase in number

of games in the last decade, it is concluded that maritime serious gaming entrepreneurship is still in its infancy.

With regard to the games, it is found out that all companies except for Company-A are using VR technology in their serious games. This means companies tend to utilize enhanced technology in maritime serious gaming, which might facilitate availability of effective maritime serious games. Besides, all the discovered games aim to develop hard (technical) skills of the players. It is believed that games on maritime soft skills are also needed as soft skills facilitate application of hard skills in real life environment.

In addition to maritime companies, there are some projects involving development of maritime serious games. To start with "Marine Litter in Europe Seas: Social Awareness and Co-Responsibility" (MARLISCO) project which was supported by the European Union took place between 2012 and 2015. As a result of this project, "Sea Dream Team" game was developed for training players against marine littering (MARLISCO, 2015). Besides, the "CREAMARE" project funded by European Union aims to produce digital applications and products including 3D serious games to promote cultural heritage and raise awareness against maritime pollution and other environmental threats to oceans. The project duration is 36 months from June 2022 to June 2025 and total budget is a 1.338 million Euro (CREAMARE, 2022). Another maritime serious gaming project is "Port of the Future", developed by not-for-profit "Deltares Institute". This game aims to support port management for ensuring sustainable development of the ports (DELTARES, 2018). More example of successful maritime serious gaming projects can be given as a sign of their increasing popularity in maritime entrepreneurship ecosystem.

3. METHODOLOGY

3.1 Proposed Serious Game Design Model

The SGDM model, which is depicted in Figure 3.1, includes 8 consecutive steps for designing a maritime serious game from scratch. The SGDM model intends to practically guide the designer from the beginning of the design process to the end of it. More specifically, the input of the SGDM model is a maritime serious game idea and the output is a serious game design which is ready to be developed.

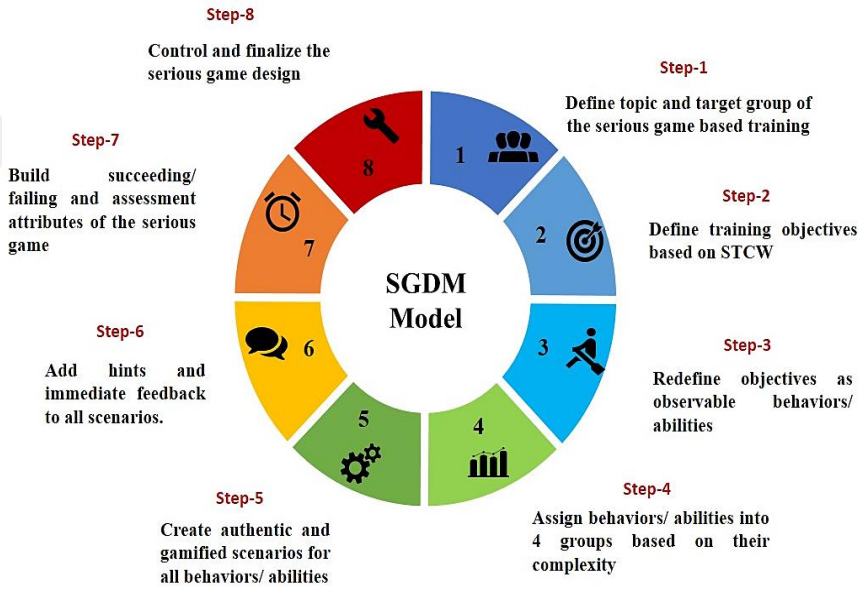

Figure 3.1: Proposed SGDM model.

In Step-1 of the SGDM, the topic and target group of the training are defined. After that, objectives of the training should be defined based on the Knowledge, Understanding, and Proficiency column of STCW as per Step-2. If the training is not a STCW-based training, training objectives should be defined by the designer according to other maritme conventions and legislations as well as customized training requirements

In Step-3, these objectives are defined as observable behaviors/abilities. One objective can be explained as one or multiple target behaviors/abilities. If objectives are already in forms of observable behaviors/abilities, this step is not required. Covering the training objectives in terms of observable behaviors conforms well to the constructivist (Jonassen, 1999) and experiential learning theories (Kolb, 1984) as these theories support experience-based training. In Step-4, behaviors/ abilities should be grouped into 4 quadrants of the Rigor& Relevance Educational Alignment Framework (Daggett and Jones, 2010) based on their intricacy level. For assigning each target behavior/ability to the correct quadrant of the framework, the cognitive competency level and application level of each behavior/ability should be defined separately as high or low. The quadrant of each behavior/ability will be defined based on the combination of these two levels.

In Step-5, realistic scenarios are created starting from the Quadrant A behaviors/abilities and continue with the Quadrant B, C, and D. Scenarios should consist of realistic situations including onboard challenges. One or more scenarios can be created for each of the target behaviors/abilities provided that all behaviors/abilities are covered in the scenarios. Different levels of the game will consist of scenarios which are created for different quadrants of behaviors. This means, scenarios for the Quadrant A and Quadrant D behaviors will be in the first and last levels of the game for ensuring the increasing difficulty of the game levels. Involving the learners in realistic scenarios is in alignment with the constructivist and experiential learning theories because these theories state that effective learning takes place through realistic personal experiences rather than instruction. Besides, players have the chance to link their previous knowledge to realistic scenarios, which can enhance learning according to situated learning theory (Brown et al., 1989).

In Step-6, hints and feedback are added to the game. More comprehensive and corrective feedbacks should be provided after wrong answers/reactions of trainees so that they can learn from their mistakes. Hints should fade out as the player moves forward in the game. Additional hints can also be added to the scenarios, which the player can choose to see in exchange for punishment score points. Since hints and immediate feedbacks are closely related with the player interactions, they can be important for promoting the learning with an experiential learning perspective.

As per Step-7, succeeding and assessment features are created. For the succeeding/failing features, how many points the player wins/loses for the correct/incorrect answers should be decided according to the difficulty of the questions and their importance to real life competencies. Similarly, the minimum score the player needs to get to win the game should be decided. In this step, final verbal assessment about future training needs of the player should also be created based on the final score in the game. Finally in Step-8, the serious game design is reviewed and finalized by making necessary improvements.

To the extent of our knowledge, SGDM is the first serious game design model which is specific to maritime domain. By means of a case study, a holistic and applicable methodology for the design and development of maritime serious games is also provided.

Constructivist learning theory (Jonassen, 1999), experiential learning theory (Kolb, 1984) and situated learning theory (Brown et al., 1989) are integrated in the SGDM model for accomplishing the learning (cognitive) outcomes of maritime serious games. These theories are used in the model to meet the specific needs of the maritime domain. The proposed SGDM model is believed to be holistic and adaptable to different serious game ideas because it can be used no matter the topic of the game, the platform on which it will be used or software/tool by which it will be developed. We would like to further emphasize that the research objective is closely rooted in the literature review of serious games and the industrial survey of serious gaming in the maritime domain. For this reason, it is believed that this study offers a theoretical contribution to the literature as well as a practical contribution to the maritime domain.

Using the SGDM model for maritime serious game design (instead of any other model) provides 2 important advantages. Firstly, since SGDM model is specific to the maritime domain, it employs the learning theories that are specifically selected to meet the demands of the domain. For this reason, it is believed that SGDM, compared to other models, has a greater potential to help the researchers and practitioners design effective maritime serious games. Secondly, it is believed that SGDM model can provide more practical guidance than the majority of serious game design models for design of effective serious games as most of the models theoretically explain the design process rather than proposing specific design steps.

3.2 ML@S and MRA@S Game Design Using SGDM Model

3.2.1 ML@S game design

During the design process, each step of the SGDM model was consecutively applied. Achievements after each step of the SGDM model are summarized in Figure 3.2.

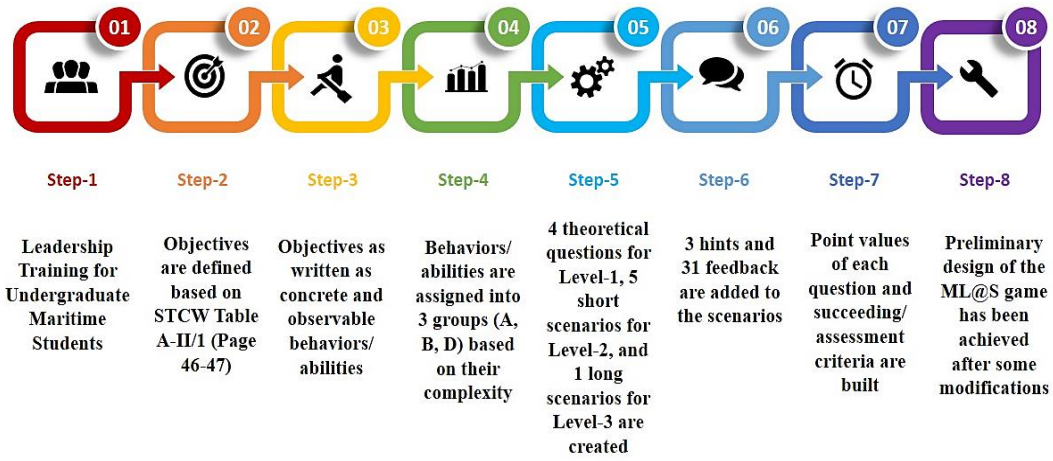

Figure 3.2: Achievement after each step of SGDM model.

Two important points about the design process should be highlighted. Firstly, the order of design steps can be modified by the designer during the design process. For instance, the designer can create succeeding/failing and assessment attributes (Step-7) and the scenarios (Step-5) simultaneously and add hints and feedback (Step-6) afterwards. In addition, the design of the game should be prototyped in a simple but representative format so that everyone who is involved in the development process can easily understand the serious game design. In this regard, the preliminary design of ML@S was depicted as a sketch diagram (not included in this study), which enabled an easier development by providing a clear explanation of the design.

As per the Step-1 of the SGDM model; the target group was defined first. Because the scenario of the game was brainstormed as taking place on the bridge of a ship, the target group of the training was decided to be deck students in MET institutions, who already had theoretical bridge resource management and leadership training. It is believed that the game can be more useful and effective if the player already has theoretical information on the topic. It is also perceived that the ML@S, in addition to leadership and teamwork skills enhancement, can also be utilized in preparation for

bridge simulator training and for assessment of deck students after completing their cadetship programs onboard.

After defining the target group, objectives of the game were defined based on STCW. Objectives of the gama are taken from Knowledge, Understanding and Proficiency column of STCW 2010. If the training is not about a STCW based competency, objectives should be taken from another document or defined by the designer based on customized training requirements of the company. The game objectives are depicted in Table 3.1.

In Step-3, these objectives are defined as observable behaviors/abilities. Then in Step-4, defined observable behaviors/ abilities are grouped into 4 quadrants of the Rigor& Relevance Educational Alignment Framework (Daggett & Jones, 2010) based on their intricacy level. Assigned quadrants for each observable target behaviour are depicted in Table 3.2.

Table 3.1: Objectives of the ML@S game.

Number	Objective
O1.	Knowledge of shipboard personnel management and training,
O2.	A knowledge of related international maritime conventions, recommendations, and national legislation,
O3.	Ability to apply task and workload management including:
O3.1	Planning and co-ordination
O3.2	Personnel assignment
O3.3	Time and resource constraints
O3.4	Prioritization
O4.	Knowledge and ability to apply effective resource management:
O4.1	Allocation, assignment, and prioritization of resources
O4.2	Effective communication onboard and ashore
O4.3	Decisions reflect consideration of team experiences
O4.4	Assertiveness and leadership including motivation
O4.5	Obtaining and maintaining situational awareness
O5.	Knowledge and ability to apply decision-making techniques:
O5.1	Situation and risk assessment
O5.2	Identify and consider generated option
O5.3	Selecting course of action
O5.4	Evaluation of outcome effectiveness

As per Step-5, the scenarios for all observable behaviors were created in 3 levels. Behaviours in Quadrant-A and Quadrant-B were covered in Level-1 and Level-2

respectively while behaviours in both Quadrant-C and Quadrant-D were included in Level-3. Brief information about the scenarios of each level is given below.

Table 3.2: Quadrants assigned for each observable target behaviour.

	Behaviour	Quadrant
O1B1	Having theoretical knowledge of shipboard personnel management	A
O1B2	Having theoretical knowledge of shipboard personnel training	A
O2B1	Having theoretical knowledge of related maritime conventions	A
O3B1	Applying planning and coordination	D
O3B2	Applying personnel assignment	C
O3B3	Applying time and resource constraints	C
O3B4	Applying task prioritization	C
O3B5	Applying task distribution	C
O3B6	Applying workload management	C
O4B1	Applying allocation, assignment, and prioritization of resources	D
O4B2	Encouraging open communication and feedback onboard and ashore	B
O4B3	Applying clear and effective communication	B
O4B4	Showing consideration of and support for team members	B
O4B5	Showing authority and assertiveness	B
O4B6	Keeping motivation of team members high despite difficulties	B
O4B7	Obtaining and maintaining situational awareness	D
O5B1	Defining and diagnosing the problem timely and correctly	D
O5B2	Generating timely and effective solution options to the problem	D
O5B3	Assessing risks and outcomes and choosing the correct option	D
O5B4	Checking the outcome of the applied solution and updating it if necessary	D

3.2.1.1 Level-0: "Understanding the Key Terminology"

The player is the master of a merchant ship M/V MARITIME LEADERS-1. The master is on the bridge. 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 and they are experienced. The duty of the 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 not any malfunction or failure in any system onboard the ship.

3.2.1.2 Level-1: "Answers First!"

Since this level covers objectives which require only theoretical knowledge, the player is asked four theoretical questions about leadership and teamwork skills. Each question follows one another and explanatory feedback shows up after each answer.

3.2.1.3 Level-2: "Rise with Your Team!"

This level involves objectives of high application and low cognitive complexity. In this level, the player, as the master, 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 behaviors in Level-3.

3.2.1.4 Level-3: "Save Your Ship!"

In this level, the player is trained about objectives with high application and high cognitive complexity. For this reason, this is the main and most difficult level of the game. In this level, 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 in which the player needs to avoid collision to win the game.

After creating the scenarios of the game, hints and feedback were added to the scenarios as suggested by Step-6 of the SGDM model. Feedback was used after all answers for improving the instructional aspect of the game. More comprehensive and knowledge-building feedback was presented after wrong answers (compared to correct answers) so that the player can develop the necessary skills by learning from his/her mistakes. Then, as per Step-7 of the SGDM model, succeeding/failing and assessment features were developed. In this regard, the player starts the game with 100 points and loses points for each incorrect answer/reaction, which costs 2 point in Level-1, 3 points in Level-2, and 5 points in Level-3. Moreover, the player has 120 or 90 seconds for answering each theoretical question in Level-1 and 90 seconds for his/her reactions in Level-2 and Level-3. If not provided within these time limits, answers/reactions are assumed incorrect. The player needs to both avoid collision and score higher than 70 points to be successful in the game. The player will fail in case of a collision regardless of the score. The game also provides an assessment about the training need of the player. The succeeding/failing criteria and assessment of the game are depicted in Table 3.3. the design is controlled, finalized abd updated in Step-8.

Table 3.3: Succeeding/failing criteria and assessment of ML@S.

Possible Outcome	Result	Assessment
Collision (Regardless of Score)	Fail	The player needs comprehensive training urgently
Collision avoided/ 0-59 Points	Fail	The player needs comprehensive training urgently
Collision avoided/ 60-69 Points	Fail	The player needs comprehensive training but the need is not urgent
Collision avoided/ 70-89 Points	Pass	The player needs training only on the failed target behaviours
Collision avoided/ 90-100 Points	Pass	The player already has required competencies. Future trainings should be conservational

3.2.2 MRA@S game design

Maritime Risk Assessment at Sea (MRA@S) game is a platform for risk assessment training on enclosed space entry operations. MRA@S focuses on the key requirements of Ship Inspection Report (SIRE) Programme of Oil Companies International Marine Forum (OCIMF). SIRE Programme, initiated in 1993, provides assessments of tanker owners and operators regarding the operational deficiencies and non-conformities of tankers and barges based on the Programme standards (OCIMF, 2021).

The design of the MRA@S is also conducted using the SGDM model. As per SGDM Step-1, the scope of the module is defined as risk assessment onboard tanker ships. In fact, the game is rooted in two SIRE 2.0 clauses. The first clause is clause # 5.7.6 which is “Were the Master, officers and ratings familiar with the company procedures for risk assessment, as appropriate to their duties, and was there evidence of the development and review of the development and review of risk assessments in accordance with the procedures?” (OCIMF, 2022; 527). The second clause is the clause # 5.1.4 which is “Were the Master and officers familiar with the shipboard emergency for enclosed space entry rescue, and had drills taken place to test the effectiveness of the shipboard emergency response plan in accordance with company procedures?” (OCIMF, 2022; 269).

Purpose of the game is providing a mentoring platform to support pre-vetting inspection trainings about risk assessment. The game is conceptualized in a risk assessment meeting before an enclosed space entry operation. Target group of the serious game is all officers on tanker ships except for chief engineers. In the game, the

player is in the role of a competent person, who will manage the meeting. Other actors in the game are responsible officer, entry crew (2 people who enter the enclosed space), attendant and rescue team leader. While the target group plays the module for training, masters, chief engineers, maritime inspectors, marine superintendents, operation managers etc. can be their mentors. Mentors can pause the game whenever they need to for providing guidance in order to make the module a more effective training experience for the target group.

In Step-2, objectives of the module are defined based on SIRE 2.0 clause # 5.7.6 (OCIMF, 2022; 527). This clause explains 5 risk assessment steps citing International Safety Guide for Oil Tankers and Terminals sixth edition (OCIMF et al, 2020) as industry guidance. These steps are identifying the hazards, deciding who might be harmed and how, evaluating the risks and deciding on preventative/mitigating measures, recording significant findings and reviewing the assessment (OCIMF, 2022; 527). 4 of these steps (excluding recording the significant findings) are chosen as objectives of the module.

In Steps-3 and 4, game objectives are classified based on their intricacy level by using Rigor Relevance Educational Alignment Framework (Daggett and Jones, 2010). Identifying hazards is assigned to Quadrant B and included in Level-1 of the game. Similarly, deciding who might be harmed and how is assigned to Quadrant C and covered in Level-2. Besides, evaluating the risks and deciding on preventative/mitigating measures is assigned to Quadrant D and included in Level-3. Finally, reviewing the assessment which requires evaluating whether hazards are adequately controlled is regarded to be the most difficult game objective (Quadrant D) and thus covered in the last level (Level-4).

In Step-5, scenarios are created for the game objectives following the order of Level-1 to Level-4. There are 1, 2, 4, and 4 (total of 11) scenarios in each Level respectively. Scenarios are interpreted below including the key terminology.

3.2.2.1 Level-0: Understanding the key terminology

The player is a competent person on a tanker ship M/T Maritime Gamentor. A team of 2 seafarers are to enter the chain locker, which is considered as enclosed spaces because of the risk of dangerous atmosphere. IMOs Safety of Life at Sea (SOLAS)

Regulation III/19 (IMO, 2013) necessitates regular drills and special entering and rescue procedures for such spaces.

In enclosed space entry, competent person conducts risk assessment about the entire process. In the game, the player is to conduct the risk assessment in the safety meeting. Additionally, responsible officer authorizes permit to entry after making sure all the safety procedures are applied as required. The attendant maintains a watch outside of the enclosed space for the safety of entry team, maintaining communication and starting the rescue procedures in case of an emergency (IMO, 2011).

3.2.2.2 Level-1: Identifying the hazards

In Level-1, the player tries to identify hazards that create risks for safety of the operation. In order to do that, the player needs to consider current situation, experiences, and technical knowledge. Level-1 includes 1 scenario, in which the player will be asked a theoretical question about the hazards in chain locker.

3.2.2.3 Level-2: Considering those in danger

In Level-2, the player, taking into account all hazards, is to define how the crew might be harmed. In this level, the player should closely consider physical and mental conditions of the crew. This step of the risk assessment will help the player manage present risks in next levels. Level-2 consists of 2 scenarios. In the first scenario (Scenario-2), the player notices that one of the entry crew looks exhausted and should make a decision about him after thoroughly analyzing the situation. In the second scenario (Scenario-3), the player inspects the personal protective equipment to be used by 2 entry crew for defining the missing one.

3.2.2.4 Level-3: Evaluating and mitigating the risk

In Level-3, the player is to analyze the level of risks in the scenarios by considering likelihood and severity of the potential harms. In this level, the player needs to decide if the risks in the scenarios are tolerable or a risk mitigating action is required. Risk analysis in this level should also be used in Level-4 for evaluating the effectiveness of the precautions.

Level-3 includes 4 scenarios. In the first three scenarios (Scenarios-4, 5, and 6), the player will consider shape of the chain locker, the rust in there, and an oil tank which is adjacent to the chain locker respectively, taking into account their effects on risk

analysis. In the last scenario of the level (Scenario-7), the player should make an overall assessment of the potential hazards. This assessment will affect the procedures to be followed and precautions to be taken for the enclosed space entry.

3.2.2.5 Level-4: Evaluating the Control Measures

In Level-4, which is the final level, the player should review the overall risk assessment and evaluate if potential hazards are effectively controlled. Because the chain locker entry is assessed to be risky in Level-3, additional control measures such as personal multi gas meters, protective clothing and rescue harnesses are necessary for the entry personnel. The player will assess existing control measures, consider potential hazards, the risk analysis about them and effectiveness of the measures together to evaluate the acceptability of the current measures.

Level-4 includes 4 scenarios. In these scenarios (Scenarios-8, 9, 10, and 11), the player is to evaluate the utilization of atmospheric testing device, radio communication, ventilation, and personal multi gas meters respectively.

Now that the scenarios are ready, the feedback was added for all the scenarios in order to enhance the instructive aspect of the game. Different feedback was created for correct and incorrect reactions in the scenarios for personalization. After correct reactions, feedbacks included general points about risk assessment while they were more constructive and comprehensive after incorrect reactions.

After that, as suggested by Step-7 of SGDM model, succeeding/failing criteria of the game were created. In this regard, the player has 100 points at the beginning of the module and loses points for incorrect answers/reactions. Incorrect answers/reactions worth 4 points in Level-1, 8 points in Level-2 and Level-3, and 12 points in Level-4. In addition, the player has 2 minutes for each answer/reaction after getting involved in the scenario. The player needs to score 72 or higher to be successful in the game. The game also makes an evaluation about training needs of the player based on their score. Succeeding/failing criteria and evaluations of the module are shown in Table 3.4. The design is finalized as per Step-8 of SGDM.

Table 3.4: Succeeding/failing criteria and assessment of MRA@S.

Score	Result	Assessment
0-59	Fail	The player needs comprehensive and constructive training urgently
60-71	Fail	The player needs comprehensive and constructive training. The need is not urgent.
72-87	Pass	The player needs short constructive training on topics s/he made mistake about.
88-100	Pass	The player already has the required risk assessment competency. Future trainings should be conservational.

3.3 Game Prototypes

After the preliminary designs, both games were ready to be prototyped. Deciding the game engine to be used was the first step of prototyping.

A game engine can be defined as the main software constituent of game development which is used for rendering, visualization, physics, and interaction design in games (Bergeron, 2005). For making this decision, compatibility with the target platform(s), the programming language to be used in the game engine, capability of asset import from other sources, user-friendly interface, graphical and visualization capabilities, and animation editing are among the important criteria to take into account (Wu & Kaushik, 2015).

After considering these criteria, Unity3D® (Version: 2019.4.12f1) game engine was selected for prototyping the games for Windows® and Mac® platforms.

Unity3D is a multi-platform game engine created by Unity Technologies. Unity3D includes 3D graphics, graphical user interface, audio, physics engine, networking components and graphics rendering and scripting features for software development. It supports scripting on JavaScript, C# and Boo programming languages with quick iteration time (Unity, 2020). User-friendly real time navigation in the game and easy object manipulation features are also among the advantages of Unity3D® (Stojanovic et al., 2013). Whether they are games or not, Unity3D is also used for developing virtual reality and augmented reality applications (Jiang, 2017). Unity3D was successfully used in this study. Especially thanks to compatibility with different platforms, ready-to-use assets, as well as easy scripting features with C# programming

language, it is believed that Unity3D can be further used for development of maritime 3D serious games.

The games has been protoyped as a result of about 1.5 years of hard work. I worked together with a game developer during the protyping process as it involved high amount of coding on Unity3D game engine through C# programming language. This collaboration enabled me to create game prototypes with enhanced visual graphics, providing a more realistic game environment in the experimental study conducted with the students.

An online gamified mentoring platform namely Maritime Gamentor, available at www.maritimegamentor.com, was created for the purpose of this study. Two game prototypes (ML@S and MRA@S) were conceptualized as modules of maritime gamentor platform where they are publicly available.

3.3.1 Maritime leaders at sea (ML@S) game

After the design, ML@S was prototyped on Unity3D® (Version: 2019.4.12f1) for Windows® and Mac® platforms. Unity3D was successfully used in this study. Especially thanks to compatibility with different platforms, ready-to-use assets, as well as easy scripting features with C# programming language, it is believed that Unity3D can be further used for development of maritime 3D serious games.

Moreover, Blender® modeling platform is another tool which has been used for the development process. Blender® is a free and open source modeling platform which is compatible with Linux, Windows and Mac systems. Blender can be used for 3D mesh models, animation control, 2D/3D texture mapping, internal rendering, supporting external rendering, lighting control, 3D sculpting, video editing and node editing. Different file formats such as blend, OBJ, JPEG, PNG, GIF, FITS, AVI, MPEG, MOV can be imported to and exported from the Blender environment (Blender, 2021). In our study, some of the 3D objects and animations were firstly developed on Blender and then transferred to the Unity3D environment.

Prototyping the ML@S game required a hard work. Following a multidisciplinary game development approach (with game developers, 3D artists etc.) might decrease development time and enhance authenticity, engagement of players and thus effectiveness of the game.

Although there are considerable amount of work in the literature on different structures of game elements, there is not an agreed upon taxonomy (Dicheva et al., 2015). For example Hunter and Werbach (2012) offered 3 groups of game elements which are game dynamics, game mechanics, and game components. Similarly, Bedwell et al. (2012) also proposed a taxonomy of game elements to be used with educational purpose. In this regard, we created a framework of the game elements to provide insight on serious game prototyping/development in the maritime domain.

During the prototyping process, we assigned elements of the ML@S game into 3 groups, which create the game when they get together. The main purpose of this assignment is providing a more straightforward understanding of the game elements and how they can be developed on Unity3D. These groups are Game Assets, Game Rules as well as Game Events and Interactions. These groups and game elements under each group are depicted in Figure 3.3.

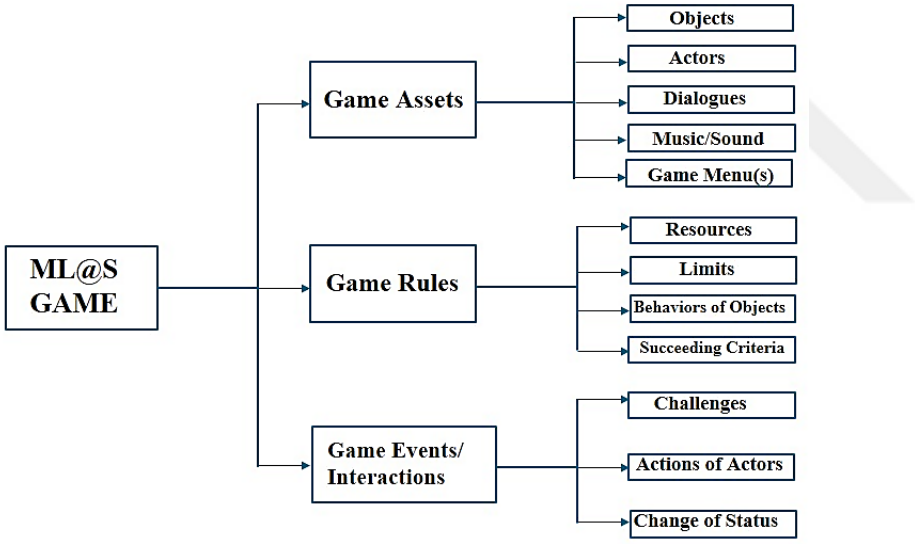

Figure 3.3: Groups of the game elements.

Out of these game elements, game assets were developed first. For creating game objects and actors, readily available Unity3D assets were used. Additionally, dialogues in the game were created by scripting. For adding music and sound effects, the Audio Source object of Unity3D was utilized and timed by scripting. Moreover, Canvas elements of Unity3D were utilized for screen rendering, which enabled us to create game menus. Outside view of M/V Maritime Leaders-1 ship and the bridge of the ship where the game takes place are depicted in Figures 3.4 and 3.5 respectively.

Figure 3.4: Outside view of M/V Maritime Leaders-1.

Figure 3.5: Bridge of M/V Maritime Leaders-1.

After the game assets, game rules were developed. For this purpose, Class and Methods features of Unity3D have been used. Classes have been defined for each element of rules and the rules are created as methods under these classes by scripting. For example, for depicting points of the player in the game, showing the time left in the scenario and assigning behaviors to objects (like helmsman and 3rd Officer), classes of points, time, helmsman, and 3rd Officer were added. After defining their classes, their changes and behaviors are represented by Methods. Figure 3.6 shows the 3rd

Officer and the helmsman while Figure 3.7 shows the lookout during a navigational watch on the bridge with points property added to the game.

Figure 3.6: 3rd Officer and Helmsman during a navigational watch.

Figure 3.7: Lookout during a navigational watch.

Finally, game events and interactions were added to the game. For doing this, challenges and actions of actors were created as Methods by scripting. Then, the challenges and associated actions of actors which are based on the decision of the player were called up using the various Trigger functions in Unity3D. This way, the branching in the game was achieved, allowing the game scenario to continue according to the changes in the status of the game. Figure 3.8 shows the presentation of a challenge in the scenario. For instance, future behaviors of the helmsman will be affected based on the reaction of the master to him in this challenge. Figure 3.9 depicts the feedback for the wrong reaction to the challenge in Figure 3.8.

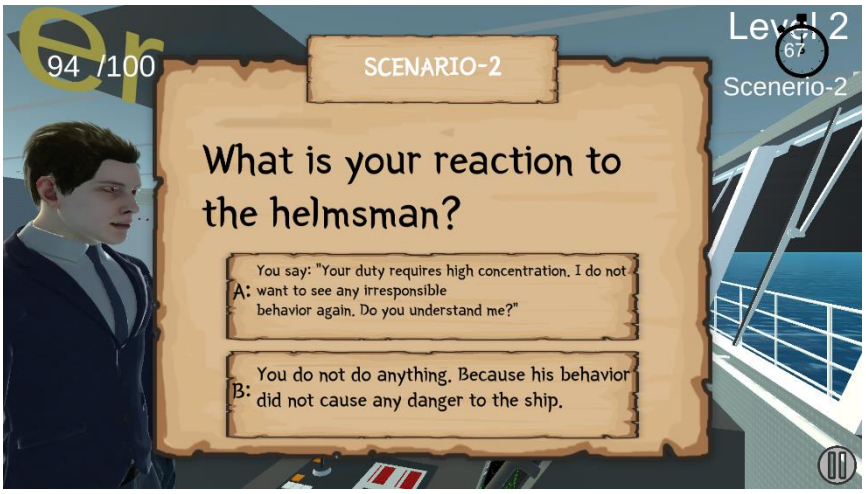

Figure 3.8: A challenge in the scenario.

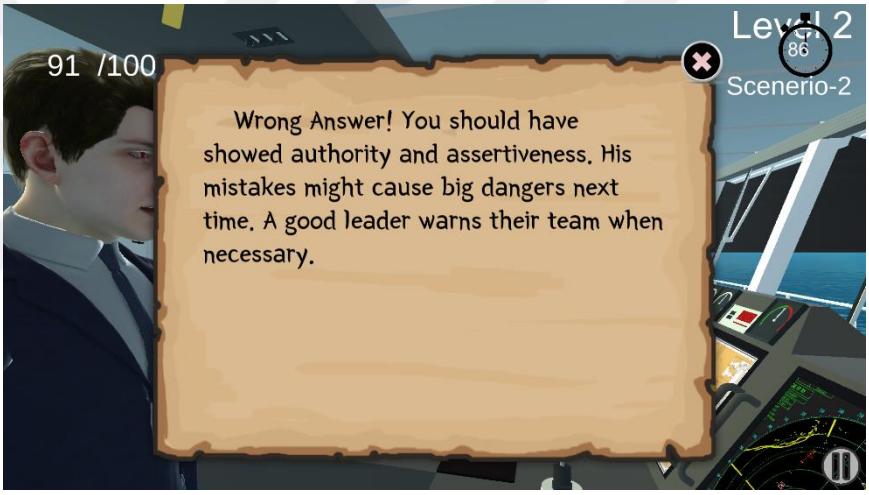

Figure 3.9: Feedback for the challange in Figure 3.8.

3.3.2 Maritime risk assessment at sea (MRA@S) game

Prototyping of MRA@S game was also started with game environment and game objects. Ready-to-use Unity3D® assets and Blender® platform were also employed to develop game environment and objects. Outside view of the tanker ship M/T Maritime Gamentor and a scene from the risk assessment meeting are depicted in Figure 3.10 and Figure 3.11 respectively.

Figure 3.10: Outside view of M/T Maritime Gamentor.

Figure 3.11: A scene from the risk assessment meeting.

After that, the dialogues and sound effects were created scripting in C# and utilizing the Audio Source object of Unity3D®. A sample dialogue from the game is shown in Figure 3.12. The game menus were created using Canvas elements of Unity3D®, which is an element used for screen rendering.

Figure 3.12: A sample dialogue.

Then the scoring and timing features as well as the behaviors of the player and crew were developed. With this purpose, separate "Classes" in Unity3D® was defined for scoring and timing features as well as the actors in the game. Then, their behaviors were added under their "Classes" as "Methods" through scripting in C# programming language. Figure 3.13 shows the player while checking the personal protective equipment with scoring and timing features added to the module.

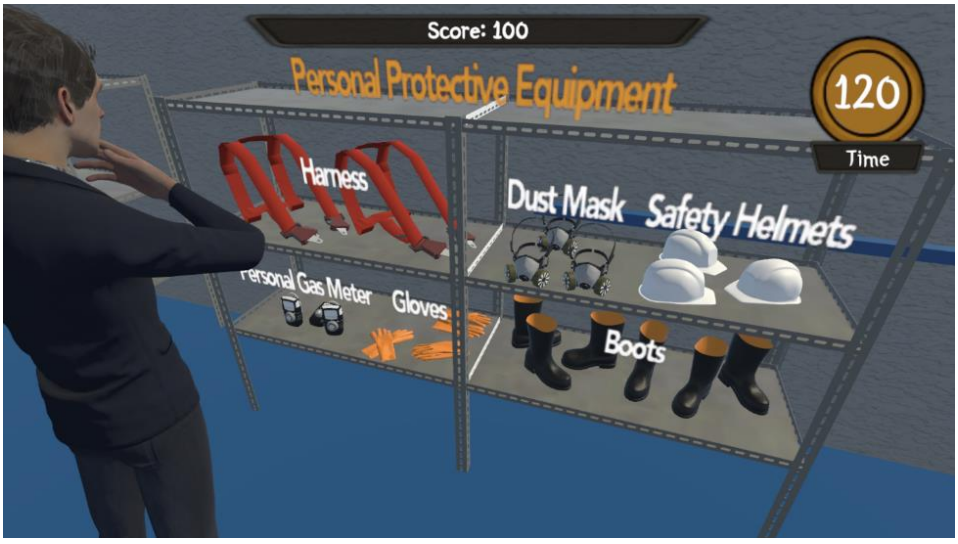

Figure 3.13: Player while checking personal protective equipment.

Finally, the game scenarios, questions and feedbacks were created. They were also created as "Methods" by scripting in C# language. They were then called at the correct time in the scenarios by using "Trigger" functions in Unity3D®. The scenarios are firstly presented in the game, which are followed by associated questions and

feedbacks. Scenario-8, Question-8 (for the scenario-8) and associated feedback for the incorrect answer are depicted in Figure 3.14, Figure 3.15 and Figure 3.16 respectively.

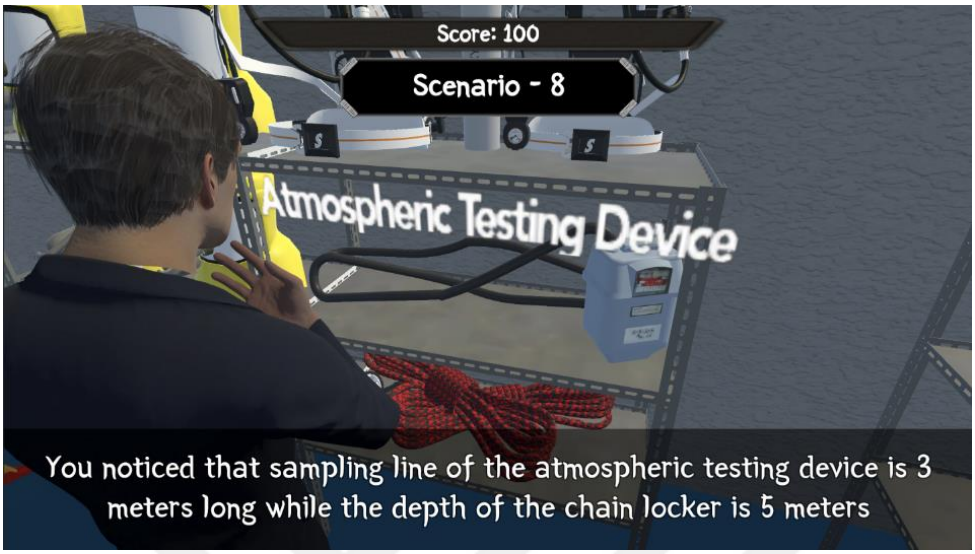

Figure 3.14: Scenario-8 of the game.

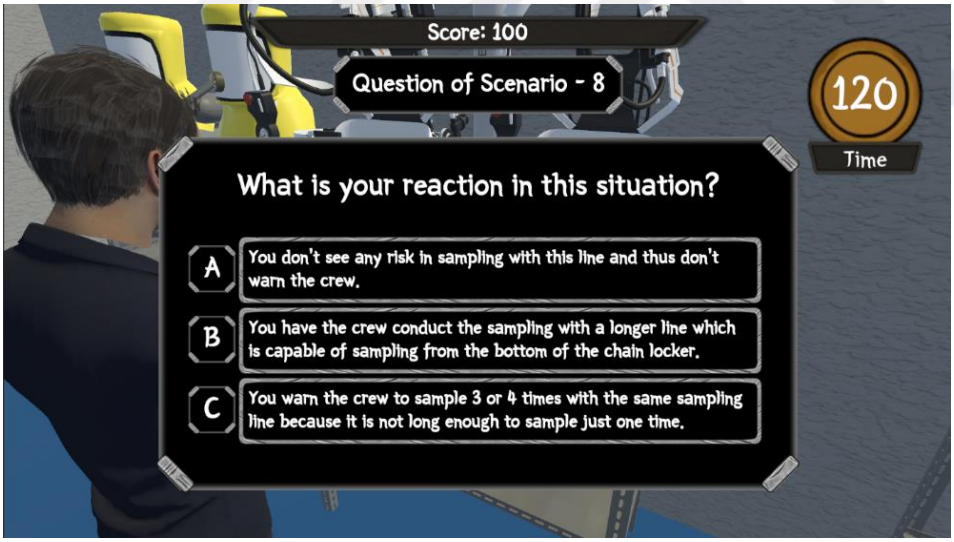

Figure 3.15: Question-8 for scenario-8.

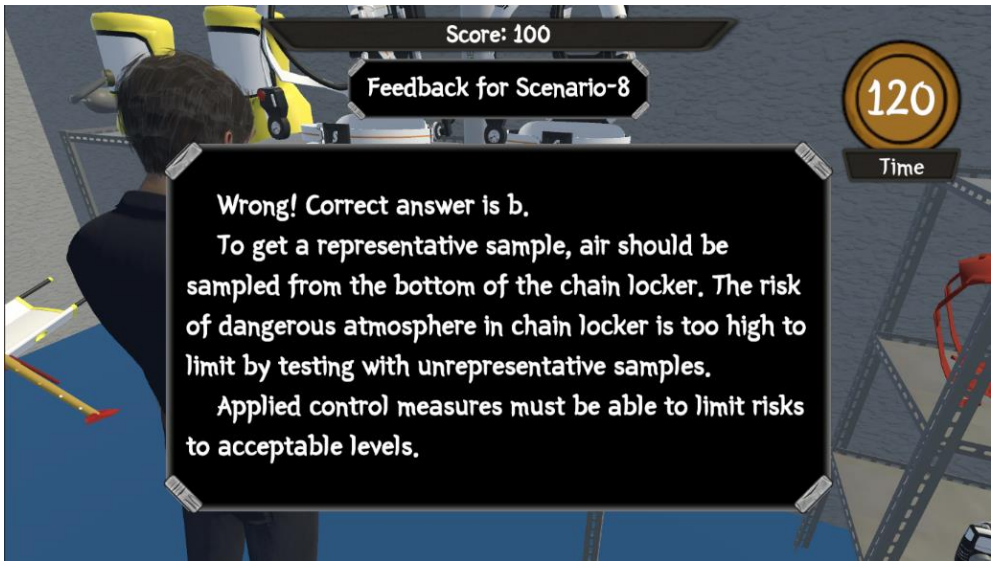

Figure 3.16: Feedback of the incorrect answer for question-8.

4. EXPERIMENTAL STUDY

The aim of the experimental study is to assess and validate the ML@S game by investigating the maritime students' perceptions and attitude towards it. In broader perspective, this chapter intends to provide insight into design and utilization of maritime serious games. This chapter proposes the procedure of the experimental study as well as explaining the data collection and statistical tools and methods used in the study.

4.1 Procedure and Participants

This quantitative experimental study took the survey and correlational research approach (Creswell, 2011) where experiences and perceptions of the students are evaluated through a survey and the correlation between them is statistically analyzed. In May 2023, 76 maritime undergraduate students played the ML@S game and then answered a 27-question survey on their experiences and perceptions about the game. All the students were comprehensively informed about the experimental study and their role in it and their verbal consent were granted before the study.

The experimental study was conducted remotely in 3 online sessions as the classes were being held online during the time of the study. 86 undergraduate maritime students attended the online sessions and 76 (88 %) of them actually completed the study. 30, 36, and 10 students completed the study in the first, second and third session respectively. The sessions lasted about 2 hours. In the first 30 minutes of the sessions, students were familiarized with the overall study and ML@S game. Then the students downloaded and played the game for about one hour. In the final 30 minutes of the sessions, the students answered the survey about their perceptions on the game.

The participants of the study were undergraduate maritime students in İstanbul Technical University Maritime Faculty. Maritime Transportation Engineering program. All the students were deck students. 70 (92%) of the students were male and 6 (8%) of them were female. 20 (26%) of the students were from the 1st class, 45 (59%) of them were from 2nd class, 5 (7%) of them were from the 3rd class and 6 (8%) of them were from the 4th class of the school. 40 (53%) of these students reported taking theoretical leadership education at school before. In addition, 44 (58%) students reported playing at least 1 serious game and 6 (8%) students reported playing a maritime serious game before. Characteristic information about the students are presented in Table 4.1 below.

Table 4.1: Characteristic information about the students.

Class	Gender	Took Leadership Education Before?	Played SG Before	Played Maritime SG Before
1th:20	Male:70	Yes:40	Yes:44	Yes:8
2nd: 45	Female:6	No:36	No:32	No:68
3nd: 5				
4th: 6				

Information about the students' previous gaming habit and perception about playing computer games were also collected for the purpose of the study. In this regard, 8 (%10.5), 17 (%22), 18 (%24), 15 (%20), 8 (%10.5), 10 (%13) students reported playing computer games less than 1 hour, 1 to 4 hours, 5 to 10 hours, 11 to 15 hours, 16 to 20 hours and more than 20 hours a week respectively. Besides, 25 (%33) students reported that they certainly enjoy playing computer games while 2 (%3) of them declared that they certainly do not enjoy it. Collected information about previous gaming habit and perception about playing computer games is depicted in Table 4.2 and Table 4.3.

Table 4.2: Previous gaming habits of the students (hours in a week)**.**

≤ 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 4.3: Gaming perception of the students (I enjoy playing computer games).

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

4.2 Data Collection

4.2.1 The survey

After the students play the ML@S game, a survey was applied to measure their experiences and perceptions towards the game The survey included 27 questions and applied to the students through e-mail. The questions required close-ended answers on a 6-point Likert Scale with 1 as “Certainly Disagree” and 6 as “Certainly Agree”.

For creating survey questions, the literature was 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”, where 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; Franco-Mariscal et al, 2015). Measuring the future intentions of students on playing ML@S or similar games was already a clear aim of the survey. In this regard, the questions were created under 4 categories, which are; “Motivation and Engagement”, “Perceived Usefulness”, “Perceived Ease of Use” and “Intention on Future Use”. The survey questions are depicted in Table 4.4 below.

Table 4.4: 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 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
Perceived Usefulness	8. The game has enhanced my leadership skills 9. The game is useful for maritime education 10.The game will change my leadership behaviors onboard ships 11.Playing the game enabled me learn more quickly than theoretical education 12.The game increased the quality of my learning experience. 13.The game increased my interest in leadership and teamworking education 14.The 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. 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

4.2.2 Gameplay data

The experimental study also utilized learning analytics perspective for making more detailed analysis of students' learning experience. Learning Analytics (LA) is defined as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" (Long, Siemens, Conole, & Gaŝevîc´, 2011). LA can increase the quality of teaching and learning practices by analyzing learners' interactions and

supporting evidence-based educational decision making (Syed et al, 2019). LA also fosters self-regulated, adaptive and personalized learning (Schumacher and Ifenthaler, 2018) by providing the learners with accurate and timely information and feedback about their learning process.

Taking a learning analytics perspective, some gameplay data is recorded to be used in the statistical analysis and thus better understanding 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 4.5.

Table 4.5: Recorded gameplay data.

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

All data recorded is used in the analysis. To start with, game score and lost points in each level data is 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 was also analyzed to gain insight into behaviors 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.

4.3 Data Testing

The survey and gameplay data is then analyzed using IBM SPSS ® Version 28. Data analysis included normality test, sampling adequacy analysis as well as validity and reliability tests. Statistical methods utilized are also explained in this section. Results of descriptive analysis and the experimental study are provided in Chapter 5.

4.3.1 Normality testing

The survey and gameplay data is firstly tested for normality. On this behalf, Table 4.6. depicts the associated skewness and kurtosis values for the survey and gameplay data. A normal distribution means that there is neither skewness nor kurtosis. The survey and gameplay data can be regarded as normally distributed since the skewness and kurtosis of the data are within the range of -3 to 3 (Farrell and Rogers-Stewart, 2006).

Table 4.6: Skewness and kurtosis values for the data.

Data Type	Skewness	Kurtosis
Motivation and Engagement Survey	-2.09	7.50
Perceived Usefulness Survey	-1.59	5.31
Perceived Ease of Use Survey	-0.60	1.09
Intention on Future Use Survey	-2.06	9.72
Game Score	0.09	-0.19
Total Game Time	-0.43	0.70
Lost Points in Level-1	0.96	-0.57
Lost Points in Level-2	0.79	-0.90
Lost Points in Level-3	-0.30	-0.23
Total Time in Level-1	0.79	0.38
Total Time in Level-2	-1.83	4.58
Total Time in Level-3	-0.41	1.12
Level-1 Time on Questions	0.23	-0.58
Level-1 Time in Scenarios	1.26	1.84
Level-2 Time on Questions	0.88	0.42
Level-2 Time in Scenarios	1.36	1.92
Level-3 Time on Questions	0.09	-0.55
Level-3 Time in Scenarios	-0.46	1.23

4.3.2 Sampling adequacy testing

Kaiser-Meyer-Olkin (KMO) and Bartlett tests have been performed to analyze 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 and Fidell, 2013). KMO test result of 0.854 in our study confirmed that the collected data was adequate for factor analysis. The Bartlett Sphericity test result

of p=0.000 (p<0.5) also validated the correlation within the collected data and confirmed that factor analysis can be applied to it.

4.3.3 Validity testing

Validity explains if an instrument correctly measures what it is supposed to measure (Sekaran and Bougie, 2010). In this study, validity of the dataset was tested through examining convergent validity and discriminant validity. Convergent validity explains if the items measuring the same construct are correlated while discriminant validity ensures that constructs that are not supposed to be related are indeed unrelated (Hair et al, 2014).

For examining convergent validity, factor loadings were firstly calculated through factor analysis. The calculated factor loadings are included in Table 4.7. Factor loadings are positively correlated with the contribution each item (question) has to what it intends to measure. Item reliability can be examined from factor loadings of each item. 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 and Bougie, 2010). As this is the case in our study, we conclude that our study has convergent validity.

Table 4.7: Factor loading values for the survey questions.

Question	Factor Loading Value
1.	0,594
2.	0,673
3.	0,486
4.	0,593
5.	0,687
6.	0,667
7.	0,582
8.	0,576
9.	0,485
10.	0,723
11.	0,618
12.	0,751
13.	0,781
14.	0,774
15.	0,853
16.	0,848
17.	0,702
18.	0,803
19.	0,594
20.	0,415
21.	0,669
22.	0,773

Table 4.7 (continues): Factor loading values for the survey questions.

Question	Factor Loading Value
23.	0,816
24.	0,882
25.	0,866
26.	0,783
27.	0,754

Looking at the discriminant validity, the Heterotrait-Monotrait (HTMT) ratio of correlation values was computed and shown in Table 4.8. As shown in the table, all HTMT values were below 0.8, confirming discriminant validity of our study (Hair et al.,2014).

Table 4.8. HTMT ratio of correlation values.

	Motivation and Engagement	Perceived Usefulness	Perceived Ease of Use	Intention on Future Use
Motivation and Engagement	-	-	-	-
Perceived Usefulness	0.341	-	-	-
Perceived Ease of Use	0.455	0.581	-	-
Intention on Future Use	0.392	0.446	0.414	-

4.3.4 Reliability testing

Reliability (or internal consistency) refers to how consistenly 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 (depicted in Table 4.9). The Cronbach's Alpha values for each category of items and the overall survey were 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).

Table 4.9: Cronbach Alpha values for survey questions.

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

4.4 Statistical Methods Used in Data Analysis

This section explains the methods used for the data analysis after data testing. The results acquired as a result of the analysis are presented in Chapter-5.

4.4.1 Analysis of variance (Anova) test

Analysis of variance (ANOVA) is a test that defines test statistics using the means and variances of the data. Utilizing the test statistics, whether there is a difference or not between groups of data is then determined. When performing a test with ANOVA, the null hypothesis is defined as there is no difference between groups all groups are the same and the null hypothesis is accepted if p value is above the threshold value (confidence level) (Neideen and Brasel, 2007). In this study, ANOVA test is used to analyze if the ML@S game scores and total game times differ among different student groups with different gaming hours in a week.

4.4.2 Pearson Correlation Coefficient Test

The Pearson Correlation Coefficient Test is used for evaluating the correlation of two continuous variables. If the correlation coefficient “r” value is 1, this tells us that two variables are completely correlated, and if it is zero, this means there is no correlation at all. The “r” value can also be negative symbolizing the negative correlation between the variables (Foster et al, 2001). Although there are different approaches in the literature, in this study it is assumed that r values lower than 0.3, between 0.3 and 0.5, and above 0.5 represent weak, medium strength, and strong correlation as put forward by Cohen (1988).

4.4.3 Independent sample t-test

The independent samples t-test compares the means within the data to explore if there is a statistically meaningful difference between the two groups. It is assumed that there

is a significant difference between the groups for “p” values less than 0.05 and vice versa (Dimitrov and Rumrill, 2003). In this study, independent samples t test is used for analyzing if students in different groups report statistically different perceptions in the survey or display different behaviors in the game.

4.4.4 Scheffe test

The Scheffe test is used to explore if means of various groups meaningfully differ. This test calculates all possible contrast between means and thus sensitive for complex comparisons rather than pairwise comparisons. (Scheffe, 1956; Hinkle et al, 1982). In this study, Scheffe Test is used together with ANOVA test to further analyse from which group the difference stems from.

4.4.5 Benferroni test

The Bonferroni Test is also used for determining the differences between various groups of data. In the Benferroni Method, a multiple-comparison correction is applied to prevent data from incorrectly appearing to be statistically significant (false positives) (Bland and Altman, 1995). This method has been criticized that it might increase the risk of false negative results, especially with large number of datasets (Dunn, 1961). In this study, Benferroni Test is used together with the Scheffe Test (after the ANOVA test) in order to determine from which groups of students the difference or similarity result from. This way, minimizing the risk of false negatives and false positives and thus acquiring more dependable results is targeted.

5. RESULTS

This chapter presents the results of the statistical analysis conducted for answering the Research Question-5. To achieve this objective, results of the descriptive analysis are firstly provided. Then, results of further statistical anlysis are explained. This chapter also includes a discussion regarding the acquired results within the perspective of the overall study.

5.1 Descriptive Analysis

The analysis in this section provides a short summary of the research variables. It is believed that the results of the descriptive analysis will 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 finished the game in 789.80 seconds (approximately in 13.5 minutes) in average. In fact, the average time encountered is lower than anticipated before the experimental study. Minimum and maximum total game time of the students varied within 320 and 1289 seconds. The wide range of total game time variation might be a sign of different motivation and engagement or perceived ease of use of the students, which is aimed to be explored by surveying them. The descriptive statistics of game score and total game time is summarized in Table 5.1 below

Table 5.1: The descriptive statistics of game score and total game time.

	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

Looking at the students' answers in the survey, we conclude that they mostly have positive perception about the game. 61.3 % of the students stated that they either agreed or certainly agreed to have motivation and engagement in the game. The average of students' answer to this group of questions is 4.68, which is between slightly agree and agree. Besides, 65.2 % of the students perceived (agreed or completely agreed) the game as useful for their leadership skills. The average answer to the perceived usefulness questions is 4.81, which is between slightly agree and agree, being 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. Average answer in this group is 4.94, which is close to agree. Moreover, 77 % of the students stated that they are willing to use similar serious game in the future for educational purposes. The average of the answers about future intention is 5.00, which means agree in the scale. The general frequency table of the students' answers in the survey is depicted in Table 5.2.

Table 5.2: General frequency table of students' answers in the survey.

Group of Question	**Item**	**Frequency**	**Percent**
Motivation and Engagement	Certainly Disagree (1)	7	1.3
	Disagree (2)	3	0.6
	Slightly Disagree (3)	40	7.5
	Slightly Agree (4)	156	29.3
	Agree (5)	219	41.2
	Certainly Agree (6)	107	20.1
		Total: 532	**Average: 4.68**

Table 5.2 (continues): General frequency table of students' answers in the survey.

Perceived	Certainly Disagree (1)	7	1.3
Usefulness	Disagree (2)	2	0.4
	Slightly Disagree (3)	39	7.3
	Slightly Agree (4)	137	25.8
	Agree (5)	196	36.8
	Certainly Agree (6)	151	28.4
		Total: 532	**Average: 4.81**
Perceived	Certainly Disagree (1)	1	0.1
Ease of Use	Disagree (2)	4	0.8
	Slightly Disagree (3)	47	6.8
	Slightly Agree (4)	153	22.3
	Agree (5)	251	36.7
	Certainly Agree (6)	228	33.3
		Total: 684	**Average: 4.94**
Future Use	Certainly Disagree (1)	4	1.3
	Disagree (2)	0	0
	Slightly Disagree (3)	4	1.3
	Slightly Agree (4)	62	20.4
	Agree (5)	146	48
	Certainly Agree (6)	88	29
		Total: 304	**Average: 5.00**

Having presented the general statistics of the survey answers, the answers to some key questions are presented in this part of the study. Firstly, 65.8 % of the students agreed or certainly agreed to have fun in the game. Considering the importance of fun feature for a game, it is believed that this aspect of the game should be improved. 50 % of the students explained that they were highly engaged throughout the game, which can also be improved by enhanced fun features. Besides, 63.2 % of the students told that game graphics attracted their attention, which is regarded as a topic that might be improved.

Moreover, 75.1 % of the students stated that the game enhanced their leadership skills and 71.1 % of the students regarded the game as useful for maritime education. 48.7 % of the students agreed or certainly agreed that the game was clear and understandable and 47.3 % of the students felt that they were in complete control of

the game. Looking at this particular result, it might be concluded that game scenarios and game flow should be made more clear to the players so that they feel more control and engagement towards the game. Finally, 69.8 % of the students said that they would use serious games at school and 75.1 % of the students explained that they would prefer serious games to theoretical education at school. Frequency table of some key answers in the survey is shown in Table 5.3.

Table 5.3: Frequency table of some key answers in the survey.

Question	Item	Frequency	Percent
I had fun playing the game	Certainly Disagree (1)	1	1.3
	Disagree (2)	0	0
	Slightly Disagree (3)	6	7.9
	Slightly Agree (4)	19	25
	Agree (5)	38	50
	Certainly Agree (6)	12	15.8
	Average	-	4.69
I was highly engaged and involved in the game from beginning to the end	Certainly Disagree (1)	1	1.3
	Disagree (2)	0	0
	Slightly Disagree (3)	9	11.9
	Slightly Agree (4)	28	36.8
	Agree (5)	25	32.9
	Certainly Agree (6)	13	17.1
	Average	-	4.51
Game graphics attracted my attention and enhanced my willingness to play	Certainly Disagree (1)	1	1.3
	Disagree (2)	2	2.6
	Slightly Disagree (3)	6	7.9
	Slightly Agree (4)	19	25
	Agree (5)	27	35.6
	Certainly Agree (6)	21	27.6
	Average	-	4.73
The game has enhanced my leadership and team working skills	Certainly Disagree (1)	1	1.3
	Disagree (2)	0	0
	Slightly Disagree (3)	4	5.2
	Slightly Agree (4)	14	18.4

Table 5.3 (continues): Frequency table of some key answers in the survey.

	Agree (5)	28	36.9
	Certainly Agree (6)	29	38.2
	Average	-	5.03
The game is useful for maritime education and training	Certainly Disagree (1)	1	1.3
	Disagree (2)	0	0
	Slightly Disagree (3)	2	2.6
	Slightly Agree (4)	19	25
	Agree (5)	33	43.5
	Certainly Agree (6)	21	27.6
	Average	-	**4.92**
ML@S serious game increased the quality of my learning experience	Certainly Disagree (1)	1	1.3
	Disagree (2)	0	0
	Slightly Disagree (3)	7	9.2
	Slightly Agree (4)	21	27.6
	Agree (5)	34	44.8
	Certainly Agree (6)	13	17.1
	Average	-	4.65
The game was clear and understandable	Certainly Disagree (1)	0	0
	Disagree (2)	1	1.3
	Slightly Disagree (3)	10	13.1
	Slightly Agree (4)	28	36.9
	Agree (5)	25	32.9
	Certainly Agree (6)	12	15.8
	Average	-	4.48
It was easy for me to become in complete control of the game	Certainly Disagree (1)	1	1.3
	Disagree (2)	1	1.3
	Slightly Disagree (3)	18	23.8
	Slightly Agree (4)	20	26.3
	Agree (5)	21	27.6
	Certainly Agree (6)	15	19.7
	Average	-	4.36
I will use similar serious games if made available to me	Certainly Disagree (1)	1	1.3
	Disagree (2)	0	0
	Slightly Disagree (3)	1	1.3
	Slightly Agree (4)	21	27.6

Table 5.3 (continues): Frequency table of some key answers in the survey.

	Agree (5)	31	40.8
	Certainly Agree (6)	22	29
	Average	-	4.93

5.2 Results of the Experimental Study

This section presents the acquired results in the experimental study for providing insight into design, development and utilization of maritime serious games. In fact, these results intents to answer Research Question-5 of the study, which is "What are the experiences and perceptions of undergraduate maritime students towards the prototyped Maritime Leaders at Sea (ML@S) game as well as maritime serious games in general?".

5.2.1 Result-1:

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

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

5.2.2 Result-2:

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

One way Anova test (F=2,596, p=0,033) has showed that there is a statistically significant relationship between previous gaming habit and total time the players spend in the game at 95 % confidence level. Besides, Bonferroni Test revealed that the students who play 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).

5.2.3 Result-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 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.

5.2.4 Result-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) depicted at 95 % confidence level that there is no statistically significant relationship between gaming perception and total game time of the students.

5.2.5 Result-5:

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

Independent sample t test (t=2,196, p=0,031) 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.

5.2.6 Result-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 results 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.

5.2.7 Result-7:

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

Independent sample t test results between taking leadership education before and perceived motivation and game effectiveness are presented separately 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 showed at 95 % confidence level that there is no statistically significant relationship between previous leadership education and their perceived motivation and game effectiveness.

5.2.8 Result-8:

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

Pearson Correlation Coefficient test results 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=-,365, p=0,001, p<0,05). Yes, medium strength relationship (0,3<r<0,5)

Level-3: (r=-,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).

5.2.9 Result-9:

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

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

Level-1: (r=-,324, p=0,004, p<0,05) Yes, medium strength relationship (0,3<r<0,5)

Level-2: (r=-,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 statistically significant medium strength and weak (Cohen, 1988) correlation in Level-1 and Level-2 respectively, but no correlation in Level-3 .

5.2.10 Result-10:

Is there a statistically significant relationship between the total time on tasks (spent 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-3: (r=0,203, p=0, 0,079, 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.

5.2.11 Result-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.

5.2.12 Result-12:

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

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

5.2.13 Result-13:

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

5.2.14 Result-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) 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.

5.2.15 Result-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) showed 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.

5.2.16 Result-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 ($r=0,234$, $p=0,042$, $p<0,05$) depicted 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.

6. CONCLUSION

6.1 Conclusion

Main objective of this study is proposing a holistic conceptual approach for effective design, development and utilization of serious games in maritime domain. More specifically, this study intends to provide the academicians and practitioners with a foundational basis for creating and using maritime serious games.

For accomplishing this, a systematic literature review of the serious game design approaches with a focus on how they support development of future skills was firstly conducted. As a result of this review, 32 serious game design approaches were defined, 8 of which support the chosen 5 (out of 11) future skills. The supported future skills are critical thinking, problem-solving, communication, collaboration and teamwork, and social skills. It was also found out that social learning and problem-based learning are most commonly utilized learning theories while clear goals and interactivity are most commonly adopted game design elements by serious game design models. In addition, one of the most significant findings of this literature review was that there has not been a serious game design model which is specific to maritime domain, which was regarded by the researcher as an urgent need for effective utilization of maritime serious games.

This literature review conducted for the purpose of this study is believed to offer important contributions to different actors. Firstly, as this study adds knowledge to the serious game literature by summarizing how design approaches support future skillsdevelopment, it can be useful for the reseachers and their sponsors in the industry. In addition, the review can be beneficial to serious game designers, educators, software engineers, as well as program officers and government officials in educational technologies as it analyzes strengths and weaknesses of the serious game design approaches, This analysis also has the potential for contributing to development of more effective serious games. Finally, since this review intends to provide an insight

into the future skill development through serious gaming, it can be benefited by students, educators and different industrial actors also within this perspective.

Based on the findings from the literature review, SGDM model, which is known to be the first serious game design model specific to maritime domain was proposed. It is believed by the researcher that SGDM model offers two important advantages for maritime serious game design. Firstly, it aims to provide a practical and step-by-step guidance for serious game design. Secondly, it is rooted in the learning theories such as educational alignment, problem-based learning, as well as experiential and constructivist learning theories, that were chosen to fulfill the specific needs of maritime domain.

Using the proposed SGDM model, this study designed two serious games taking a design-based research perspective. The serious games were then prototyped as case studies using Unity3D® game engine. In line with the main objective, current study explains the design and development processes from beginning to the end for proposing a holistic methodology for the design and development of serious game-based trainings in the maritime domain. In this regard, this study provides researchers and practitioners with practical guidance for creating similar training applications.

It is believed that the design and development methodology offered by this study has both practical and theoretical contribution to the literature as well as different actors in the maritime domain. Firstly, offered methodology and SGDM model can be utilized by researchers for conducting similar studies and developing similar maritime serious games. Besides, the serious games developed for the purpose of this study have the potential to be used for education and training of students in maritime faculties as well as in cadetship training programs of young seafarers by maritime companies. Likewise, the functions of Maritime Gamentor platform can be extended by developing other serious game based training modules on various topics such as crew familiarization, fire fighting, life saving equipments, bridge resource management etc. On this behalf, it is believed that this research can be useful for different maritime actors such as online maritime training companies, shipping companies, maritime faculties and maritime start-ups.

After prototyping the games, an experimental study was conducted for analyzing the efficiency of the ML@S game and proposed SGDM model. It can be concluded from

the experimental study that the game was tested successful by the students in all 4 categories (motivation and engagement, game effectiveness, game clearness, future use) as their average remarks were between 'I slightly agree' and 'I agree'. This being the case, it can be put forward that the developed ML@S game can be used as a means of leadership education and training. Looking at the broader picture in the study, it was proved that the SGDM model can be practically applied to design successful maritime serious games.

The experimental study also provided us with some valuable insight into design and utilization of maritime serious games. To start with, the study proved that gaming hours in a week was related to the students' serious gaming success (Result-1) and time spent in the serious game (Result-2). Besides, it was also shown that previous gaming perception of the students had statistically significant relationship with their serious gaming motivation (Result-15) and success (Result-3). From these findings, it can be theorized that serious games can be applied on a voluntarily basis to students who play games more often and likes to play game.

In addition, it was figured out in the study that the students who previously took leadership class scored higher in the game (Result-5) and spent more time in Level-3 (Result-6). In this regard, it might be useful if serious games are applied as a supplementary means of maritime education and training after the theoretical classes.

The study also discovers that the students who spend more time in the scenarios were more successful in the game (Result-8). Besides, the students with higher motivation and engagement regarded the game as more effective (Result-14). These students also tended to spend more time in the game (Result-16) and had higher intention on future use of similar serious games (Result-13). Although the finding in Result-11 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 students spend more time in the games and the games are more useful for them.

In sum, serious games can provide maritime students and young seafarers with the practical education and training they need in a cost effective way. For this reason, it is believed that serious games have a significant potential for competency development in maritime domain. In fact, one of the most significant contribution of this study is

intended to be emphasizing this potential. Current study just takes a small step to effectively design, develop, and utilize serious games in the maritime domain. For accomplishing this, it is regarded that full cooperation between researchers, industry actors, and maritime policy makers is required.

6.2 Discussion

This research idea was initiated by the researcher and advisor in June 2020 when an international maritime serious gaming company applied to ITU Maritime Faculty for selling their serious games. In fact, we were considering other topics to study at that time, but after investigating the serious games of before mentioned company, we found out that there was a certain need for improvement of the serious games we investigated. Besides, Covid-19 pandemic came out affecting all over the world and fostering the utilization of online education. As a technology enhanced method of online education, me and my advisor believed that utilization of serious games in maritime domain offered a great potential and might be a beneficial topic to study.

As the first step of the study, granting access from different serious gaming companies, I investigated various maritime serious games which are commercially available in the market. During the investigation, I noted down the points which I believe need to be improved and also offer a useful perspective to serious gaming. This review enabled me to gain valuable insight into the conceptual approach I need to offer in my study.

After reviewing commercial maritime serious games, next step of my study was critically investigating the scientific studies on serious game design. In this regard, I conducted a literature review of serious game design model, with a special focus on future skills development. As a result of this literature review, I determined 32 studies, which provide a practical and step- by-step serious game design approach. Surprisingly, I could not identify any design approach for domains such as aviation, maritime, and offshore which require a high amount of practicality and where emerging skills are of paramount importance. At that point, I decided to create a serious game design model which is specific to maritime domain and is able to practically guide both the academicians and practitioners through the design of maritime serious games. In broader perspective, I defined the **main objective of the study as proposing a holistic conceptual approach for effective design, development and utilization of serious games in maritime domain.**

After that, SGDM model, which is known to be the first serious game design model which is specific to maritime domain is offered. SGDM model guides the designers from an idea of a serious game to the design of it. It is believed that SGDM model offers two important advantages in comparison with using any other serious game design model. Firstly, since it is specific to the maritime domain, it utilizes the learning theories, namely Rigour& Relevance Educational Alignment Framework (Daggett and Jones, 2010), constructivist (Jonassen, 1999) and experiential learning theories (Kolb, 1984), which are particularly chosen to fulfill the needs of the maritime domain. For this reason, SGDM has a more important potential than other models to facilitate the design of more effective and useful maritime serious games. Secondly, it is believed that SGDM model is more successful than the majority of the reviewed serious game design models in providing practical and step-by-step guidance as most of them theoretically explain the design process instead of guiding the researchers to design similar serious games. However, it is regarded that Step-5 of the model (Creating gamified scenarios for all behaviors) model might be enhanced in a way that it can provide more specific and tailored guidance on the design of the scenarios. Honestly, I have tried hard to accomplish this by modifying the Step-5 or adding an additional step to the model but could not achieve this, leaving it as a future study.

For providing a holistic approach, I then designed two maritime serious games using SGDM model. Firstly, ML@S game intends to promote leadership and teamwork skills of undergraduate maritime students. Secondly, MRA@S game aims to provide a mentoring platform to support pre-vetting inspection trainings on board tanker ships. This way, I applied the SGDM model to design serious games for different target groups, both for maritime students and the officers onboard ships, aiming to explore its' utilization both by the faculty and industry.

After designing serious games, they were developed as prototypes using Unity 3D ® game engine. For facilitating easier development, I categorized the game elements into the 3 groups namely game assets, game rules and game events/interactions for a more straightforward and structured development process. The prototyping process started with the game assets such as objects, actors, game menu, and environment. The next step was developing the game rules including scoring and timing features, behaviours of the actors, resources, and succeeding criteria. Finally, game events/interactions such as challenges, and change of status in the game providing the branching feature were

added to the game. Based on my experiences, this study also includes guidance about developing the game elements on Unity 3D ®. It is believed that this way current study also assists the academicians and practitioners with the game development process.

Next step in the study was finalizing the development of both games. For this purpose, I was in close coordination with the domain experts from the faculty and industry. The experts explained their opinions about the compliance of the game prototypes with the STCW requirements, MET programs, and industry expectations and the prototypes were modified accordingly. After developing the games, an online open platform namely "Maritime Gamentor" was created and the games were conceptualized as modules of this platform. The games can be played online on Windows ® and Mac ® computers with no need to setup any file.

After the games were ready, an online experimental study was conducted with 76 students in Istanbul Technical University Maritime Faculty. After playing the ML@S game, the students answered a 27-question online survey regarding about their perceptions and experience about the game. It can be concluded from the experimental study that the game has been tested successful by the students in all 4 categories (motivation and engagement, game effectiveness, game clearness, future use) as their average remarks are between 'I slightly agree' and 'I agree'. The experimental study basically served two main purposes. Firstly, it has proved that the developed ML@S game can be actually played by the students and used for maritime education and training. It is believed that proving the efficiency of ML@S game also validated the SGDM model as it shows that the model can be used for designing maritime serious games. Secondly, thanks to the experimental study, some results about design, development and utilization of maritime serious games have been achieved based on the survey answers. On this behalf, the experimental study has been of vital importance for the overall study in that it proves the usability of the work conducted in the study and provides practical results based on real world application.

The main challenge I have had during the study was developing the games on Unity 3D ® using C# programming language. As programming was not my area of expertise, I had to become familiar with coding on C# first before even starting to develop the games. Besides, I often had to make unplanned technical improvements during the development process to solve the problems I encounter on the road. For instance, when I quality control the game, I noticed that the screen were freezing during the gameplay

limiting the flow of the game. Making necessary improvements to solve this issue almost took a whole month. Optimizing game controls so that the players can feel that they have full control of the game also took about a month. In addition, creating a website for setting up the Maritime Gamentor platform and modifying the game codes in order to save the gameplay data of the players were also among the time consuming technical tasks to accomplish. This being the case, design and development of the games lasted about 3 semesters although planned as 2 semesters at the beginning of the study, which caused me a little stress in the final semester trying to catch up the schedule.

Limited availability of time and resources was the main difficulty throughout the study. Stronger cooperation between maritime industry and institutions might be able to eliminate this difficulty and facilitate the design and development of effective maritime serious games. It is believed that scientific studies should strengthen this coordination by providing practical guidance for the design and development of serious games In addition, the establishment of foundational rules and regulations such as minimum standards, control procedures and mechanisms, validity and certification,is also deemed necessary for the effective utilisation of serious games in the maritime domain. Within this general picture, this study offers a fundamental basis for the design, development and utilization of novel serious games in the maritime domain.

6.3 Research Limitations and Future Work

In spite of the novel approach utilized, this study has some limitations. To start with, although a total number of 2466 studies were examined, there still is a risk of missing studies in the literature review. Performing the search with different keywords on different databases might result in finding additional studies. Similarly, we included the design models which are able to present specific steps for serious game design and this inlusion criteria might be regarded as personal affecting the number of chosen studies. For minimizing these limitations, literature review will be re-conducted for the purpose of reaching additional studies, which might also result in updating the SGDM model.

Besides, as SGDM is a newly developed model, it needs to be further utilized by another researchers for designing different kinds of maritime serious games for

proving its applicability, validity and reliability. For elimination of this limitation, additional serious games will be designed using the SGDM model and developed as modules of “Maritime Gamentor” platform. Cooperation with another researchers is also planned so that they design maritime serious games using the SGDM model and share their feedback. Further utilization of the model will serve the purposes of validating and improving it. In fact, improving Step-5 of the model (creating gamified scenarios for all target behaviors) in a way that it can guide users more specifically on creating the scenarios has priority in the future study plans.

As another limitation, the players have limited control on the functions of equipments, systems, and instruments in both games. Game graphics also limit the authenticity at some parts of the game. Upon availability of additional time and resources, these two issues are planned to be solved for increased authenticity as well as motivation and engagement of the players in the game. Besides, as serious games are games in nature, it is believed that more fun features need to be added in the games, which also has priority as a future study. Maritime Gamentor platform will be publicly available online so that as many students as possible can play the games and provide their feedback on the updated versions of the games. It is believed that the games need to be enhanced continuously based on the feedback from the players and other actors as well as latest research findings, creating an endless future study.

In addition, the developed games currently offer the same experience regardless of the position and background of the players. For enhanced instructional capability, it is believed that they need to provide the players with more personalized education and training. For eliminating this limitation, user role selection such as student, seafarer etc. including deck and engineering option, which will create different scenarios, questions and feedback in the game. For increased personalization, the existing branching in the game can also be enhanced creating more varied game scenarios and flow based on the players’ game interactions.

There are also some technical limitations to be solved regarding the gameplay method. Firstly, the developed games can only be played on Windows ® and Mac ® computers. Developing the game versions which can be played on smart phones and tablets might increase their availability to the players. In addition, although the games can currently be played online on Maritime Gamentor platform, distortion and freezing on the game screen are often encountered limiting the flow of the game. For this reason, the

experimental study was conducted by downloading the game files on personal computers rather than playing online, which removes the distortion and freezing. Improvement in the software of the game is needed for enhanced online gaming experiences.

Finally, pre-test/post-test design approach which aims to analyze the effectiveness of the game comprehensively could not be applied in the experimental study because of the limited participation and availability of the students'. Because of the same reason, only the ML@S game (but not the MRA@S game) was tested in the experimental study. Comprehensive experimental studies utilizing pre-test/post-test design approach are planned to be conducted for validation and testing of MRA@S and future serious games.

In sum, regardless of the novel results and findings, continuous enhancement of the current study is still needed, which is in fact believed to be one of the most significant rules for improvement in any scientific work.

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