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A SURVEY-BASED ASSESSMENT OF VR-ENHANCED GMDSS TRAINING

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Abstract. This paper explores the pedagogical impact and user experience of delivering Global Maritime Distress and Safety System (GMDSS) instruction in a Virtual Reality (VR)-enabled bridge simulator setting. Using immersive VR headsets, maritime students took part in a series of simulated emergency communication scenarios designed to reflect real-world operating environments. An extensive survey was carried out in order to assess participants' learning outcomes, levels of engagement, system usability, and perceived realism of the virtual bridge environment. Both Likert-scale and open-ended questions were used in the questionnaire to garner quantitative trends and qualitative insights. Initial results indicate that VR-based GMDSS training substantially enhances situational awareness, retention of procedures, and learner motivation. Respondents underscored the way the virtual bridge simulator played a critical role in enhancing their focus and self-confidence in handling GMDSS operations. However, some of the respondents underscored the physical discomfort and adaptation challenges that resulted from extended use of VR. This study provides strong evidence for the incorporation of VR technologies in maritime training and offers recommendations toward refining the design and implementation of immersive, simulation-based training modules.

Keywords: GMDS; Maritime Education and Training (MET); Virtual Reality (VR); Survey-based Assessment.

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1. INTRODUCTION

Ensuring effective communication at sea, particularly in emergency situations, has long been a critical priority for maritime safety, leading the International Maritime Organization (IMO) to establish the Global Maritime Distress and Safety System (GMDSS). Since February 1999, GMDSS has been fully enforced worldwide as part of the SOLAS (Safety of Life at Sea) Convention. The system outlines the mandatory communication equipment for ships and sets out procedures for the rescue of vessels and individuals at sea, all aimed at enhancing maritime safety to the highest possible level (Suban et al., 2010). Therefore, it is significant to learn properly for the maritime students in the scope of Maritime Education and Training (MET).

The primary function of MET is to foresee emerging challenges and offer appropriate solutions that address the future needs and expectations of shipboard crew and officers. MET plays an essential role in equipping seafarers with the competencies required to handle ship management tasks safely and efficiently. To achieve this, a comprehensive MET program should feature a well-structured curriculum that integrates both theoretical foundations and practical skills. Graduates of maritime undergraduate and postgraduate programs should acquire the necessary knowledge and training to fulfill operational responsibilities and, as they advance in their careers, attain the highest managerial qualifications (Pavic et al., 2023).

In order to ensure the safe and efficient operation of ships, it is essential that seafarers possess the necessary skills and knowledge. Recognizing the importance of maritime education, the IMO adopted the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW) in 1978. However, over time, it became evident that the convention required updates as professional standards continued to evolve. The first major revision of the STCW Convention took place in 1995, followed by a second significant revision in 2010, known as the "Manila Amendments." While the amendments introduced several changes, the most notable were the emphasis on enhancing the practical skills of seafarers and the adoption of modern training methods, including the use of simulators, distance education, online e-learning tools, and platforms (Türkistanli, 2023).

E-learning is transforming MET by offering flexible, accessible learning opportunities for seafarers (Kitada et al., 2019). It enables students to learn anytime and anywhere, improving training performance and promoting internationalization of maritime education (Chen et al., 2017). E-learning platforms like Moodle have been implemented in MET institutions, with studies showing both advantages and challenges in their adoption (Bauk et al., 2013). Research has explored the use of virtual classroom technologies, such as Multi-User Learning Environments (MUVE), to facilitate both technical and non-technical skills training for seafarers across different institutions (Kitada et al., 2019). While e-learning offers numerous benefits, including enhanced engagement and accessibility, its implementation requires careful consideration of learning theories and pedagogical approaches (Kitada et al., 2019; Bauk and Scepanovic, 2013). Ongoing research and development are necessary to optimize the integration of e-learning in MET and address current shortages in maritime education (Bauk et al., 2013). Another online learning station was developed through the MARLSD project, within which maritime students created their own deliverable methods as part of classroom activities (Duzenli et al., 2025).

Revisions to the STCW Convention and Code have driven maritime industry stakeholders to explore innovative training methods that strengthen seafarers' competitiveness in a rapidly evolving sector. This shift has compelled Maritime Education and Training (MET) institutions to embrace flexible, learner-centered approaches, ensuring that skill development and knowledge acquisition extend beyond traditional classroom boundaries (Buenaobra et al., 2018). In this context, Virtual Reality (VR) and distance learning technologies have emerged as powerful tools, offering immersive learning environments that enhance both engagement and knowledge retention. Similar to how personal computing and the Internet once revolutionized knowledge sharing and distance education, modern consumer electronics—such as smartphones, tablets, and Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) head-mounted display (HMD) systems—have introduced new possibilities for ubiquitous maritime training. These technologies, being cost-effective, portable, and adaptable, enable mobile learning, virtual environments, and distributed simulation-based training. Specifically, VR provides a computer-generated three-dimensional environment that fully immerses the user through HMDs like Oculus Rift or HTC Vive, effectively disconnecting them from the real world and allowing for highly realistic, scenario-based maritime training experiences (Mallam et al., 2019).

Some studies have addressed the integration of virtual reality technologies into higher education, with a particular focus on their cognitive and pedagogical impacts (Sánchez et al., 2000; Hamilton et al., 2020; Nisha, 2019). In parallel, several studies have explored the use of VR in maritime education and training, highlighting its potential to enhance operational skills, situational awareness, and learner engagement in simulated maritime environments (Markopoulos et al., 2019; Vukelic et al., 2023; Mallam et al., 2019). In this study, This study contributes to the growing body of research on digital transformation in maritime education by empirically examining how virtual reality (VR) technologies are perceived in the context of GMDSS training. Unlike previous studies, it focuses on a single, standardized training area with critical safety relevance, and investigates not only overall perceptions but also how these vary by gender, academic year, and prior VR experience. The findings offer valuable insights for maritime education providers, curriculum designers, and simulator developers by identifying key student-based factors influencing the acceptance and effectiveness of VR-supported training. Additionally, the results can guide the development of more personalized and adaptive digital training programs in maritime safety education. By employing a survey with both quantitative and qualitative components, this research offers valuable perspectives on the possible benefits and limitations of incorporating immersive technologies into MET.

In this context, the present study aims to examine maritime undergraduate students' perceptions and attitudes toward VR-supported GMDSS training, and to determine whether these perceptions significantly differ based on gender, academic year levels, and prior experience with virtual reality technologies. To this end, the paper is structured as follows: Section 2 describes the research methods, including survey design, data collection, and the main results; Section 3 provides a discussion of the key findings in relation to existing studies and practical implications; and Section 4 concludes the study with final remarks and recommendations for future research and practice.

2. RESEARCH METHOD

In this study, the questionnaire instrument was adapted from Cicek et al. (2021), originally validated in higher education VR studies, and recontextualized for GMDSS-specific emergency communication training. Questionnaire list is shown in the appendix part. This ensured the relevance and validity of the instrument in maritime education settings. Furthermore, the components of the research methods are the data gathering, the sample group, hypotheses, creation of the questionnaire items and the test of hypotheses identified in this part.

2.1. Data Collection

A five-point Likert-type survey was employed to investigate the antecedents and consequences related to students' preferences, interests, and perceived learning outcomes regarding the use of VR technologies in GMDSS education. The questionnaire was adapted from the validated items in Cicek et al. (2021), originally developed for assessing the use of VR in higher education, and revised to fit the specific context of maritime emergency communication training. It consisted of 27 items measured on a five-point scale ranging from strongly disagree (1) to strongly agree (5).

Using the survey approach, the suggested research model was empirically evaluated. Examining the efficacy of model structure, choosing which questionnaire questions to include or exclude, and assessing the accuracy and dependability of the data are all steps in the analysis of questionnaire replies. Likert-type questions include a statement expressing an attitude or view about the subject being searched, together with alternatives indicating the degree of agreement with that statement (Turan et al., 2015).

2.2. Sampling Group

The questionnaire survey was implemented to the participants via internet (Survey on Maritime Students' Attitudes Toward the Use of Virtual Reality (VR) in GMDSS Training Questionnaire – Google Formlar, 2025). The target group of this study consists of undergraduate students in maritime faculty, population size is 778, and maritime students studying 1st, 2nd, 3rd and 4th year in ITU Maritime Faculty. %79.8 percent students get GMDSS training in the faculty.

In this study, the questionnaire was completed by 90 participants. The majority of the participants (88.9%) were male. The distribution of students by academic year was as follows: 2.2% were first-year students, 70% second-year, 11.1% third-year, and 16.7% fourth-year students. A total of 66.7% of the participants stated that they had previously received some form of GMDSS training. Regarding VR experience, half of the students had never used a VR system before, 20% had tried it once, and the remaining participants had used it more than once. Additionally, 8.9% of the students reported that they owned a VR system at home.

The sample size of this study is 90 participants. It is also found that the margin of error value %7.85 at the %95 confidence level (Sample Size Calculator, 2025).

2.3. Hypotheses

Hypotheses of this study are listed below.

- **H1:** Maritime undergraduate students' average perception score toward VR-supported GMDSS training is significantly higher than the neutral value (test value = 3).

- **H2:** There is a statistically significant difference in perception scores regarding VR-supported GMDSS training between male and female students.
- **H3:** There is a statistically significant difference in perception scores regarding VR-supported GMDSS training among students from different academic year levels (first, second, third and fourth year).
- **H4:** There is a statistically significant difference in perception scores regarding VR-supported GMDSS training among students with different levels of prior VR experience (no experience, tried once, tried more than once).

2.4. Creation of the Questionnaire Items

In order to examine the perceptions and attitudes toward VR-supported GMDSS training, a 27-item questionnaire was initially analyzed. As a first step, the correlation matrix was reviewed to assess the interrelationships among items. Examining the correlation matrix allows researchers to determine whether the items are sufficiently related to justify a factor analysis. In this context, it is expected that each item should have a reasonable correlation (typically above 0.30) with at least one other item, indicating they are measuring a common underlying construct. Additionally, the significance values (p-values) associated with the correlation coefficients were assessed. If the significance value was greater than 0.05, it indicated that the relationship between item pairs was not statistically significant, suggesting a lack of shared variance. Such items, which do not significantly correlate with others, were considered misaligned with the construct and therefore removed from the dataset to improve the construct validity of the scale. Accordingly, items Q5, Q15, Q21, and Q22 were excluded from further analysis due to their significance values exceeding the acceptable threshold (Table 1).

Structure validity, reliability, and discriminant validity were investigated in order to assess the reflective structure in the measurement model. The various elements under each structure in the model were first defined and confirmed using principal component analysis. Particularly, the IBM SPSS Statistics version

Table 1. Correlation between 27 questionnaire items

		Variables																										
Statistics	Variables	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27
Correlation	Q1	1,000	,691	,432	,614	,117	,489	,329	,483	,353	,542	,160	,532	,558	,554	-,066	,518	,556	,463	,511	,460	,263	,270	,503	,279	,513	,437	,748
	Q2	,691	1,000	,537	,697	-,047	,630	,305	,614	,542	,646	,387	,631	,765	,568	-,035	,638	,640	,657	,535	,518	,283	,277	,493	,340	,557	,547	,767
	Q3	,432	,537	1,000	,414	,058	,364	,227	,414	,457	,403	,389	,551	,472	,615	,066	,582	,563	,510	,479	,441	,187	,277	,437	,212	,399	,516	,583
	Q4	,614	,697	,414	1,000	,034	,765	,494	,699	,659	,834	,386	,675	,637	,558	-,031	,717	,771	,730	,758	,488	,226	,313	,670	,451	,740	,671	,736
	Q5	,117	-,047	,058	,034	1,000	-,006	,064	-,017	-,008	-,054	-,067	-,119	-,053	-,035	,231	,117	,016	,017	,136	,181	-,034	,412	,003	,131	,049	,123	-,008
	Q6	,489	,630	,364	,765	-,006	1,000	,345	,689	,599	,699	,397	,599	,679	,514	-,103	,644	,644	,735	,707	,348	,284	,196	,563	,342	,743	,599	,674
	Q7	,329	,305	,227	,494	,064	,345	1,000	,327	,362	,509	,244	,435	,426	,392	-,002	,372	,398	,402	,481	,342	,225	,094	,493	,289	,441	,394	,436
	Q8	,483	,614	,414	,699	-,017	,689	,327	1,000	,508	,808	,292	,565	,550	,559	-,168	,600	,617	,605	,523	,413	,220	,143	,509	,310	,574	,495	,641
	Q9	,353	,542	,457	,659	-,008	,599	,362	,508	1,000	,566	,391	,651	,658	,502	-,062	,561	,720	,596	,620	,383	,291	,222	,604	,292	,551	,605	,535
	Q10	,542	,646	,403	,834	-,054	,699	,509	,808	,566	1,000	,313	,650	,600	,503	-,131	,663	,642	,664	,678	,371	,231	,245	,592	,338	,613	,617	,693
	Q11	,160	,387	,389	,386	-,067	,397	,244	,292	,391	,313	1,000	,452	,384	,329	,102	,368	,389	,418	,345	,510	,196	,074	,333	,380	,360	,288	,351
	Q12	,532	,631	,551	,675	-,119	,599	,435	,565	,651	,650	,452	1,000	,695	,710	-,147	,641	,720	,560	,603	,516	,438	,128	,648	,280	,642	,574	,724
	Q13	,558	,765	,472	,637	-,053	,679	,426	,550	,658	,600	,384	,695	1,000	,635	-,108	,706	,659	,670	,625	,481	,290	,242	,549	,324	,631	,634	,769
	Q14	,554	,568	,615	,558	-,035	,514	,392	,559	,502	,503	,329	,710	,635	1,000	-,161	,619	,647	,536	,531	,605	,352	,112	,598	,294	,565	,505	,672
	Q15	-,066	-,035	,066	-,031	,231	-,103	-,002	-,168	-,062	-,131	,102	-,147	-,108	-,161	1,000	,108	-,063	-,096	-,022	,135	,106	,435	-,006	,250	-,108	,039	-,110
	Q16	,518	,638	,582	,717	,117	,644	,372	,600	,561	,663	,368	,641	,706	,619	,108	1,000	,711	,656	,687	,463	,284	,359	,652	,525	,692	,725	,704
	Q17	,556	,640	,563	,771	,016	,644	,398	,617	,720	,642	,389	,720	,659	,647	-,063	,711	1,000	,734	,749	,567	,399	,266	,689	,388	,752	,681	,735
	Q18	,463	,657	,510	,730	,017	,735	,402	,605	,596	,664	,418	,560	,670	,536	-,096	,656	,734	1,000	,648	,466	,242	,281	,601	,342	,640	,649	,714
	Q19	,511	,535	,479	,758	,136	,707	,481	,523	,620	,678	,345	,603	,625	,531	-,022	,687	,749	,648	1,000	,444	,241	,278	,675	,385	,744	,707	,687
	Q20	,460	,518	,441	,488	,181	,348	,342	,413	,383	,371	,510	,516	,481	,605	,135	,463	,567	,466	,444	1,000	,350	,271	,411	,380	,335	,445	,556
	Q21	,263	,283	,187	,226	-,034	,284	,225	,220	,291	,231	,196	,438	,290	,352	,106	,284	,399	,242	,241	,350	1,000	,016	,464	,220	,273	,300	,315
	Q22	,270	,277	,277	,313	,412	,196	,094	,143	,222	,245	,074	,128	,242	,112	,435	,359	,266	,281	,278	,271	,016	1,000	,244	,432	,257	,399	,295
	Q23	,503	,493	,437	,670	,003	,563	,493	,509	,604	,592	,333	,648	,549	,598	-,006	,652	,689	,601	,675	,411	,464	,244	1,000	,575	,713	,655	,631
	Q24	,279	,340	,212	,451	,131	,342	,289	,310	,292	,338	,380	,280	,324	,294	,250	,525	,388	,342	,385	,380	,220	,432	,575	1,000	,531	,475	,353
	Q25	,513	,557	,399	,740	,049	,743	,441	,574	,551	,613	,360	,642	,631	,565	-,108	,692	,752	,640	,744	,335	,273	,257	,713	,531	1,000	,702	,680
	Q26	,437	,547	,516	,671	,123	,599	,394	,495	,605	,617	,288	,574	,634	,505	,039	,725	,681	,649	,707	,445	,300	,399	,655	,475	,702	1,000	,657
	Q27	,748	,767	,583	,736	-,008	,674	,436	,641	,535	,693	,351	,724	,769	,672	-,110	,704	,735	,714	,687	,556	,315	,295	,631	,353	,680	,657	1,000
Sig. (1-tailed)	Q1		<,001	<,001	<,001	,137	<,001	<,001	<,001	<,001	<,001	,066	<,001	<,001	<,001	,269	<,001	<,001	<,001	<,001	<,001	,006	,005	<,001	,004	<,001	<,001	<,001
	Q2	,000		,000	,000	,331	,000	,002	,000	,000	,000	,000	,000	,000	,000	,372	,000	,000	,000	,000	,000	,003	,004	,000	,001	,000	,000	,000
	Q3	,000	,000		,000	,294	,000	,016	,000	,000	,000	,000	,000	,000	,000	,267	,000	,000	,000	,000	,000	,039	,004	,000	,022	,000	,000	,000
	Q4	,000	,000	,000		,376	,000	,000	,000	,000	,000	,000	,000	,000	,000	,385	,000	,000	,000	,000	,000	,016	,001	,000	,000	,000	,000	,000
	Q5	,137	,331	,294	,376		,476	,274	,435	,469	,308	,264	,132	,310	,372	,014	,137	,442	,438	,100	,044	,375	,000	,488	,109	,322	,125	,470
	Q6	,000	,000	,000	,000	,476		,000	,000	,000	,000	,000	,000	,000	,000	,168	,000	,000	,000	,000	,000	,003	,032	,000	,000	,000	,000	,000
	Q7	,001	,002	,016	,000	,274	,000		,001	,000	,000	,010	,000	,000	,000	,492	,000	,000	,000	,000	,000	,017	,188	,000	,003	,000	,000	,000
	Q8	,000	,000	,000	,000	,435	,000	,001		,000	,000	,003	,000	,000	,000	,056	,000	,000	,000	,000	,000	,019	,089	,000	,001	,000	,000	,000
	Q9	,000	,000	,000	,000	,469	,000	,000	,000		,000	,000	,000	,000	,000	,282	,000	,000	,000	,000	,000	,003	,018	,000	,003	,000	,000	,000
	Q10	,000	,000	,000	,000	,308	,000	,000	,000	,000		,001	,000	,000	,000	,108	,000	,000	,000	,000	,000	,014	,010	,000	,001	,000	,000	,000
	Q11	,066	,000	,000	,000	,264	,000	,010	,003	,000	,001		,000	,000	,001	,169	,000	,000	,000	,000	,000	,032	,245	,001	,000	,000	,003	,000
	Q12	,000	,000	,000	,000	,132	,000	,000	,000	,000	,000	,000		,000	,000	,084	,000	,000	,000	,000	,000	,000	,115	,000	,004	,000	,000	,000
	Q13	,000	,000	,000	,000	,310	,000	,000	,000	,000	,000	,000	,000		,000	,155	,000	,000	,000	,000	,000	,003	,011	,000	,001	,000	,000	,000
	Q14	,000	,000	,000	,000	,372	,000	,000	,000	,000	,000	,001	,000	,000		,064	,000	,000	,000	,000	,000	,000	,146	,000	,002	,000	,000	,000
	Q15	,269	,372	,267	,385	,014	,168	,492	,056	,282	,108	,169	,084	,155	,064		,156	,276	,185	,419	,103	,159	,000	,478	,009	,155	,359	,150
	Q16	,000	,000	,000	,000	,137	,000	,000	,000	,000	,000	,000	,000	,000	,000	,156		,000	,000	,000	,000	,003	,000	,000	,000	,000	,000	,000
	Q17	,000	,000	,000	,000	,442	,000	,000	,000	,000	,000	,000	,000	,000	,000	,276	,000		,000	,000	,000	,000	,006	,000	,000	,000	,000	,000
	Q18	,000	,000	,000	,000	,438	,000	,000	,000	,000	,000	,000	,000	,000	,000	,185	,000	,000		,000	,000	,011	,004	,000	,000	,000	,000	,000
	Q19	,000	,000	,000	,000	,100	,000	,000	,000	,000	,000	,000	,000	,000	,000	,419	,000	,000	,000		,000	,011	,004	,000	,000	,000	,000	,000
	Q20	,000	,000	,000	,000	,044	,000	,000	,000	,000	,000	,000	,000	,000	,000	,103	,000	,000	,000	,000		,000	,005	,000	,000	,001	,000	,000
	Q21	,006	,003	,039	,016	,375	,003	,017	,019	,003	,014	,032	,000	,003	,000	,159	,003	,000	,011	,011	,000		,442	,000	,019	,005	,002	,001
	Q22	,005	,004	,004	,001	,000	,032	,188	,089	,018	,010	,245	,115	,011	,146	,000	,000	,006	,004	,004	,005	,442		,010	,000	,007	,000	,002
	Q23	,000	,000	,000	,000	,488	,000	,000	,000	,000	,000	,001	,000	,000	,000	,478	,000	,000	,000	,000	,000	,000	,010		,000	,000	,000	,000
	Q24	,004	,001	,022	,000	,109	,000	,003	,001	,003	,001	,000	,004	,001	,002	,009	,000	,000	,000	,000	,000	,019	,000	,000		,000	,000	,000
	Q25	,000	,000	,000	,000	,322	,000	,000	,000	,000	,000	,000	,000	,000	,000	,155	,000	,000	,000	,000	,001	,005	,007	,000	,000		,000	,000
	Q26	,000	,000	,000	,000	,125	,000	,000	,000	,000	,000	,003	,000	,000	,000	,359	,000	,000	,000	,000	,000	,002	,000	,000	,000	,000		,000
	Q27	,000	,000	,000	,000	,470	,000	,000	,000	,000	,000	,000	,000	,000	,000	,150	,000	,000	,000	,000	,000	,001	,002	,000	,000	,000	,000	

29.0 was used to conduct an exploratory factor analysis (EFA). EFA employing principal-component factor analysis with Direct Oblimin rotation was used to evaluate the main component in the model. The findings demonstrated that the main components had eigenvalues over 1.

Following the exploratory factor analysis, the Pattern Matrix was examined on the Table 2 to assess the factor structure of the items. Since the aim of the study was to develop a unidimensional scale measuring perceptions and attitudes toward VR-supported GMDSS training, items that loaded onto multiple components or exhibited substantial cross-loadings were removed to preserve the structural clarity and construct validity of the scale.

As a result of this refinement process, items Q3, Q11, Q14, Q20, and Q24 were excluded from further analysis due to their loadings on more than one component.

The correlation matrix was re-evaluated for the remaining survey items, and it was concluded that the items demonstrated moderate to strong inter-item correlations. Items showing moderate correlations were retained in the scale, as their significance values did not exceed the 0.05 threshold, indicating statistically meaningful relationships (Table 3). Moreover, According to Schober et al., (2018), 0.10-0.39 weak, 0.40-0.69 moderate, 0.70-0.89 strong, upper 0.89 very strong correlation between items. Except a few items correlation between 0.30-0.39, the study correlation coefficient values are upper from 0.4. Table 3 also show the positive correlations between items.

Table 2. Pattern matrix of 23 questionnaire Items

	Component		
	1	2	3
Q1	,498		
Q2	,529		
Q3		,691	
Q4	,935		
Q6	,918		
Q7	,561		
Q8	,775		
Q9	,643		
Q10	,948		
Q11		,717	
Q12	,519		
Q13	,616		
Q14		,577	
Q16	,701		
Q17	,697		
Q18	,735		
Q19	,855		
Q20		,840	
Q23	,743		
Q24	,418		,634
Q25	,909		
Q26	,760		
Q27	,657		

The results of the principal component analysis revealed that a single dominant factor accounts for 64.09% of the total variance, while the eigenvalues of the remaining components were below the threshold of 1.00. The results indicated that a single latent factor accounted for 64.09% of the total variance, suggesting a strong unidimensional structure and demonstrating a high level of construct validity for the scale measuring perceptions and attitudes toward VR-supported GMDSS training (Table 4), given that the total variance explained surpasses the recommended threshold of 60% (Steiner & Grieder, 2020).

Table 3. Correlation table between 18 questionnaire Items

		Q1	Q2	Q4	Q6	Q7	Q8	Q9	Q10	Q12	Q13	Q16	Q17	Q18	Q19	Q23	Q25	Q26	Q27
Correlation	Q1	1,000	,691	,614	,489	,329	,483	,353	,542	,532	,558	,518	,556	,463	,511	,503	,513	,437	,748
	Q2	,691	1,000	,697	,630	,305	,614	,542	,646	,631	,765	,638	,640	,657	,535	,493	,557	,547	,767
	Q4	,614	,697	1,000	,765	,494	,699	,659	,834	,675	,637	,717	,771	,730	,758	,670	,740	,671	,736
	Q6	,489	,630	,765	1,000	,345	,689	,599	,699	,599	,679	,644	,644	,735	,707	,563	,743	,599	,674
	Q7	,329	,305	,494	,345	1,000	,327	,362	,509	,435	,426	,372	,398	,402	,481	,493	,441	,394	,436
	Q8	,483	,614	,699	,689	,327	1,000	,508	,808	,565	,550	,600	,617	,605	,523	,509	,574	,495	,641
	Q9	,353	,542	,659	,599	,362	,508	1,000	,566	,651	,658	,561	,720	,596	,620	,604	,551	,605	,535
	Q10	,542	,646	,834	,699	,509	,808	,566	1,000	,650	,600	,663	,642	,664	,678	,592	,613	,617	,693
	Q12	,532	,631	,675	,599	,435	,565	,651	,650	1,000	,695	,641	,720	,560	,603	,648	,642	,574	,724
	Q13	,558	,765	,637	,679	,426	,550	,658	,600	,695	1,000	,706	,659	,670	,625	,549	,631	,634	,769
	Q16	,518	,638	,717	,644	,372	,600	,561	,663	,641	,706	1,000	,711	,656	,687	,652	,692	,725	,704
	Q17	,556	,640	,771	,644	,398	,617	,720	,642	,720	,659	,711	1,000	,734	,749	,689	,752	,681	,735
	Q18	,463	,657	,730	,735	,402	,605	,596	,664	,560	,670	,656	,734	1,000	,648	,601	,640	,649	,714
	Q19	,511	,535	,758	,707	,481	,523	,620	,678	,603	,625	,687	,749	,648	1,000	,675	,744	,707	,687
	Q23	,503	,493	,670	,563	,493	,509	,604	,592	,648	,549	,652	,689	,601	,675	1,000	,713	,655	,631
	Q25	,513	,557	,740	,743	,441	,574	,551	,613	,642	,631	,692	,752	,640	,744	,713	1,000	,702	,680
	Q26	,437	,547	,671	,599	,394	,495	,605	,617	,574	,634	,725	,681	,649	,707	,655	,702	1,000	,657
	Q27	,748	,767	,736	,674	,436	,641	,535	,693	,724	,769	,704	,735	,714	,687	,631	,680	,657	1,000
Sig. (1-tailed)	Q1		<,001	<,001	<,001	<,001	<,001	<,001	<,001	<,001	<,001	<,001	<,001	<,001	<,001	<,001	<,001	<,001	<,001
	Q2	,000		,000	,000	,002	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000
	Q4	,000	,000		,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000
	Q6	,000	,000	,000		,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000
	Q7	,001	,002	,000	,000		,001	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000
	Q8	,000	,000	,000	,000	,001		,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000
	Q9	,000	,000	,000	,000	,000	,000		,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000
	Q10	,000	,000	,000	,000	,000	,000	,000		,000	,000	,000	,000	,000	,000	,000	,000	,000	,000
	Q12	,000	,000	,000	,000	,000	,000	,000	,000		,000	,000	,000	,000	,000	,000	,000	,000	,000
	Q13	,000	,000	,000	,000	,000	,000	,000	,000	,000		,000	,000	,000	,000	,000	,000	,000	,000
	Q16	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000		,000	,000	,000	,000	,000	,000	,000
	Q17	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000		,000	,000	,000	,000	,000	,000
	Q18	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000		,000	,000	,000	,000	,000
	Q19	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000		,000	,000	,000	,000
	Q23	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000		,000	,000	,000
	Q25	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000		,000	,000
	Q26	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000		,000
	Q27	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	

Table 4. Total variance degree (left) and component matrix (right)

Component	Initial Eigenvalues Total	% of Variance	Cumulative %	Extraction Sums of Squared Loadings Total	% of Variance	Cumulative %
1	11,537	64,094	64,094	11,537	64,094	64,094
2	,987	5,483	69,577			
3	,799	4,442	74,018			
4	,749	4,163	78,181			
5	,612	3,401	81,583			
6	,510	2,835	84,417			
7	,428	2,376	86,793			
8	,384	2,135	88,929			
9	,347	1,930	90,859			
10	,293	1,628	92,487			
11	,257	1,426	93,913			
12	,246	1,366	95,280			
13	,232	1,291	96,571			
14	,189	1,051	97,622			
15	,130	,723	98,345			
16	,120	,668	99,012			
17	,098	,545	99,557			
18	,080	,443	100,000			

	Component 1
Q1	,682
Q2	,793
Q4	,898
Q6	,827
Q7	,538
Q8	,754
Q9	,745
Q10	,837
Q12	,805
Q13	,824
Q16	,832
Q17	,869
Q18	,820
Q19	,834
Q23	,781
Q25	,834
Q26	,793
Q27	,874

The component matrix obtained through principal component analysis revealed that all remaining items loaded strongly onto a single factor, with loadings ranging from .538 to .898. This supports the unidimensional structure of the scale designed to measure perceptions and attitudes toward VR-supported GMDSS training (Table 4).

The Kaiser-Meyer-Olkin (KMO) value of .930 and the statistically significant result of Bartlett's Test of Sphericity (χ^2 = 1497.89, df = 153, $p < .001$) indicate that the data set is highly suitable for factor analysis (Table 5).

Table 5. The Kaiser-Meyer-Olkin and Bartlett's Test of Sphericity values

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,930
Bartlett's Test of Sphericity	Approx. Chi-Square	1497,892
	df	153
	Sig.	<,001

The KMO measure far exceeds the commonly recommended threshold of 0.60, confirming sampling adequacy (Shrestha, 2021). Likewise, the significant Bartlett's test result suggests the presence of sufficient correlations among items. Together, these findings validate the appropriateness of the data for the factor extraction process and support the construct validity of the scale measuring students' perceptions and attitudes toward VR-supported GMDSS training.

To evaluate the internal consistency of the 18-item scale developed to measure perceptions and attitudes toward VR-supported GMDSS training, Cronbach's Alpha was calculated (Table 6). The result indicated a reliability coefficient of α = 0.964, which exceeds the commonly accepted threshold of 0.90 for excellent internal reliability (George & Mallery, 2002). This suggests that the items demonstrate a high degree of internal consistency, meaning that they consistently reflect the underlying construct. Therefore, the scale can be considered highly reliable for further hypothesis testing and statistical analyses.

Table 6. Cronbach's Alpha value

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,964	,966	18

In order to test the proposed hypotheses, the reliability and construct validity of the final version of the questionnaire items—namely Q1, Q2, Q4, Q6, Q7, Q8, Q9, Q10, Q12, Q13, Q16, Q17, Q18, Q19, Q23, Q25, Q26, and Q27—were confirmed through exploratory factor analysis (EFA). The factor loadings of all items exceeded the commonly accepted threshold of .50, ranging from .538 (Q7) to .898 (Q4), which indicates strong and meaningful contributions of each item to the underlying construct. The unidimensional structure, with a single extracted component explaining 64.09% of the total variance, further supports the theoretical coherence of the scale designed to measure students' perceptions and attitudes toward VR-supported GMDSS training. Additionally, the high Kaiser-Meyer-Olkin (KMO) value of .930 and the significant result of Bartlett's Test of Sphericity (χ^2 = 1497.89, df = 153, $p < .001$) indicate excellent sampling adequacy and sufficient inter-item correlations, thereby validating the instrument's use for hypothesis testing within the study framework. Furthermore, the internal consistency of the scale was confirmed with a Cronbach's Alpha coefficient of .964, which indicates excellent reliability and suggests that the items reliably measure the intended construct.

2.5. Testing of Hypothesis

H1: Maritime undergraduate students' average perception score toward VR-supported GMDSS training is significantly higher than the neutral value (test value = 3).

In order to test H1, which posits that maritime undergraduate students' average perception score toward VR-supported GMDSS training is significantly higher than the neutral value (test value = 3), a one-sample t-test was conducted (Table 7). The analysis revealed that the mean score of the students ($M = 4.25$, $SD = 0.75$, $N = 90$) was significantly greater than the neutral test value of 3, $t(89) = 15.844$, $p < .001$. The 95% confidence interval for the mean difference ranged from 1.094 to 1.408, indicating a consistent and statistically significant positive deviation from neutrality. Additionally, the effect size was large, as reflected by Cohen's d = 1.670 and Hedges' correction = 1.656, both of which exceed the threshold for a strong effect (0.80). These findings confirm the validity of H1, demonstrating that students perceive VR-supported GMDSS training favorably and significantly above the neutral midpoint of the scale.

H2: There is a statistically significant difference in perception scores regarding VR-supported GMDSS training between male and female students.

To examine H2, which proposed that there is a statistically significant difference in perception scores regarding VR-supported GMDSS training between male and female students, the Mann-Whitney U test was utilized (Table 8). This non-parametric test was deemed appropriate due to the unequal sample sizes between groups ($n = 11$ for females, $n = 79$ for males) and the likelihood of non-normal distribution in the smaller female group, conditions under which the assumptions of the independent samples t-test may not be met. The test results revealed no statistically significant difference in perceptions between the two groups, with $U = 360.000$, $Z = -0.919$, $p = .358$. The mean ranks for female and male students were 38.73 and 46.44, respectively, indicating only a slight, non-significant difference. Accordingly, the results do not provide sufficient evidence to support H2, and the hypothesis is therefore not supported.

H3: There is a statistically significant difference in perception scores regarding VR-supported GMDSS training among students from different academic year levels (first, second, third and fourth year).

Table 7. One-Sample Test results

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Mean	90	4,2515	,74931	,07898

One-Sample Test

	Test Value = 3						
			Significance			95% Confidence Interval of the Difference	
	t	df	One-Sided p	Two-Sided p	Mean Difference	Lower	Upper
Mean	15,844	89	<,001	<,001	1,25146	1,0945	1,4084

One-Sample Effect Sizes

				95% Confidence Interval	
		Standardizer[a]	Point Estimate	Lower	Upper
Mean	Cohen's d	,74931	1,670	1,348	1,989
	Hedges' correction	,75570	1,656	1,336	1,972

Table 8. Mann-Whitney U test results for H2

Mann-Whitney Test

Ranks

	cinsiyet	N	Mean Rank	Sum of Ranks
Mean	Female	11	38,73	426,00
	Male	79	46,44	3669,00
	Total	90		

Test Statistics[a]

	Mean
Mann-Whitney U	360,000
Wilcoxon W	426,000
Z	-,919
Asymp. Sig. (2-tailed)	,358

Table 9. Kruskal-Wallis H test results for H3

Kruskal-Wallis Test

Ranks

	sınıf	N	Mean Rank
Mean	First	2	81,25
	Second	63	48,59
	Third	10	36,40
	Fourth	15	33,83
	Total	90	

Test Statistics[a,b]

	Mean
Kruskal-Wallis H	8,860
df	3
Asymp. Sig.	,031

Table 10. Kruskal-Wallis H test results for H4

Kruskal-Wallis Test

Ranks

	VR denedin mi	N	Mean Rank
Mean	No	46	42,12
	Only one	18	39,08
	More than ones	26	55,92
	Total	90	

Test Statistics[a,b]

	Mean
Kruskal-Wallis H	6,015
df	2
Asymp. Sig.	,049

To test the hypothesis that perception scores toward VR-supported GMDSS training differ significantly among students from different academic years (H3), the Kruskal-Wallis H test was employed due to the non-normal distribution of data across groups. The results indicated a statistically significant difference among the academic year levels, $\chi^2(3) = 8.860$, $p = .031$. This finding suggests that at least one of the student groups differs in their perception scores compared to others. Specifically, the highest mean rank was observed in first-year students (Mean Rank = 81.25), while fourth-year students had the lowest (Mean Rank = 33.83), implying a decreasing trend in perceived value or enthusiasm for VR-based GMDSS training over academic progression. Therefore, H3 is supported.

H4: There is a statistically significant difference in perception scores regarding VR-supported GMDSS training among students with different levels of prior VR experience (no experience, tried once, tried more than once).

A Kruskal-Wallis H test was conducted to evaluate whether students' perception scores toward VR-supported GMDSS training differed based on their prior VR experience (Table 10). The results indicated a statistically significant difference among the three experience groups, $\chi^2(2) = 6.015$, $p = .049$. The mean rank scores revealed that students who had experienced VR more than once (Mean Rank = 55.92) reported higher perception scores compared to those with no experience (42.12) or a single trial (39.08). This finding supports H4 and suggests that increased prior exposure to VR may enhance positive perceptions toward its use in maritime training.

3. FINDINGS AND DISCUSSION

The results of the hypothesis testing yielded valuable insights into the students' perceptions and attitudes toward the use of virtual reality (VR) in GMDSS training. Below tables show the results of the study.

Firstly, H1 was supported, indicating that the overall mean perception score of maritime undergraduate students was significantly higher than the neutral midpoint value of 3. This suggests that students generally have a positive perception toward the use of VR-supported training in the context of GMDSS education. This result aligns with the growing body of

Table 11. The overall results of the hypothesis

Hypothesis	Test Applied	Result	Supported
H1	One-Sample t-Test	$p < .001$	Supported
H2	Mann-Whitney U Test	$p = .358$	Not Supported
H3	Kruskal-Wallis Test	$p = .031$	Supported
H4	Kruskal-Wallis Test	$p = .049$	Supported

research that supports the effectiveness of immersive technologies in enhancing engagement and learning in maritime education.

On the other hand, H2 was not supported, as the Mann-Whitney U test revealed no statistically significant difference between male and female students' perception scores (p = .358). This finding implies that gender is not a determining factor in shaping students' attitudes toward VR-based training, which supports the idea that immersive educational technologies can be inclusively adopted regardless of gender.

For H3, a Kruskal-Wallis test indicated a statistically significant difference in perception scores based on students' academic year level (p = .031). The mean ranks showed that first-year students had the most favorable perceptions, followed by second-year students, while third- and fourth-year students exhibited lower perception scores. This trend may reflect a novelty effect or a greater openness to technological innovation among early-year students, who may have less entrenched expectations from traditional training methods.

H4 was also supported, with significant differences found among students with different levels of prior VR experience (p = .049). Notably, students who had used VR more than once demonstrated significantly more positive perceptions toward its integration in GMDSS training compared to those with little or no prior experience. This result highlights the importance of familiarity and prior exposure in fostering acceptance of VR-based methods in educational settings.

The findings emphasize the potential of VR as an effective and positively received tool for maritime training, particularly among younger students and those with greater exposure to the technology. However, they also underline the need for structured and repeated VR experiences to cultivate broader acceptance and optimize learning outcomes across all student groups.

4. CONCLUSION

This study aimed to evaluate maritime undergraduate students' perceptions and attitudes toward the use of Virtual Reality (VR) in GMDSS training, within the broader context of digital transformation in maritime education and training. Employing a highly crafted questionnaire alongside rigorous statistical methods, namely exploratory factor analysis, one-sample t-test, Mann-Whitney U test, and Kruskal-Wallis tests, this study proved empirical support for the effectiveness and general acceptance of training modules imparted via virtual reality for maritime students.

The results show students tend to perceive VR-supported GMDSS training positively, especially among those with prior exposure to VR and those undertaking earlier stages of their studies. This finding suggests the integration of immersive technologies in maritime education is likely to enhance engagement and perceived effectiveness, especially when students are provided adequate exposure and support.

There are limitations to this study and the promising results. The small and imbalance in the sample with respect to demographics, in particular gender and academic year, might restrict the generalizability of the results. For instance, the female population was much smaller than the male, which may have had an impact on the statistical power of comparisons regarding gender. Furthermore, first and third year students also were enrolled at significantly lower numbers compared to second years and may have weighted year-based comparisons.

Subsequent research should attempt to remedy these limitations by using larger and more equal sample groups and seeking cohorts from multiple schools, or even across maritime training systems, in order to improve model generalizability. Furthermore, longitudinal research can be implemented to explore how students' perceptions change with continuous exposure of VR training environment. Subsequent studies could also combine objective performance data such as performance on simulation-based assessment tools, or real-time reaction data, to consolidate subjective perception data and provide a overview sight of VR's educational value for GMDSS course. Finally, instructor support, cognitive load, and technological familiarity might play as mediating or moderating variables to consider in student adoption and learning effectiveness in VR-assisted GMDSS training.

In conclusion, while the findings affirm the value of VR as a pedagogical innovation in maritime training, its successful integration requires ongoing efforts in instructional design, access equality, and empirical evaluation.

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APPENDIX – QUESTIONNAIRE LIST

1. Time passes more quickly if I learn GMDSS through a VR system compared to traditional 2D methods.
2. Using VR for GMDSS training increases my interest in the learning environment.
3. Even if I use VR for GMDSS training, I am always aware that I'm in virtual world and that none of it is real.
4. VR makes GMDSS learning more active, rather than passively receiving information on a screen.
5. Being fully immersed in a virtual environment during GMDSS training would make me feel uneasy.
6. The visual elements provided by VR makes GMDSS training more engaging for students.
7. It difficult to understand complex GMDSS concepts without visual or interactive representations.
8. My interest in GMDSS increases if interactive content or VR systems are used in the training.
9. Experiencing GMDSS scenarios together with classmates in a shared virtual environment are valuable.
10. Stimulating multiple senses through VR helps me understand GMDSS procedures more effectively.
11. Direct interaction with instructors and classmates remains important, even if VR is used in GMDSS training.
12. VR-based GMDSS education allows students to actively engage with the training content.
13. Being able to virtually visit maritime locations and scenarios during GMDSS training inspires me to learn more.
14. If uses in GMDSS classes, VR turns learning into a more enjoyable and entertaining experience.
15. Using VR in GMDSS training distracts students from the core learning objectives.
16. Simulated experiences in VR motivates students to explore and research GMDSS topics more deeply.
17. Students learn GMDSS procedures more effectively when they interact with the training content.
18. It is important to apply GMDSS theory to practical scenarios to master operational skills, and VR supports this.
19. In GMDSS training, peer-to-peer interaction is encouraged, with the instructor guiding the learning process.
20. In GMDSS education, the instructor remains the primary source of information and leads the training sessions.
21. Traditional exams in GMDSS training are not fully reflect a student's real knowledge or skills.
22. Traditional assessments in GMDSS training provide an accurate measure of students' knowledge.
23. Personalized evaluation through VR systems are more effective for assessing GMDSS knowledge and skills.
24. VR environments simulate GMDSS operations with the same effectiveness as real-world drills.
25. Unlike traditional methods that mostly convey facts, VR offers interactive experiences in GMDSS learning.
26. Using VR in GMDSS education fosters creativity in solving communication and emergency challenges.
27. With VR, students learn how to respond to unfamiliar or dangerous GMDSS scenarios in a safe environment.