

Development of Augmented Reality-Based Learning Media for Ship Navigation Instruments as an Educational Innovation at the Merchant Marine Polytechnic of Makassar

Endang Lestari^{1*}, M Masrupah¹, Wardimansyah Ridwan², Muhammad Hidayat L²

¹Politeknik Ilmu Pelayaran Makassar, Makassar, Indonesia

²Universitas Negeri Makassar, Makassar, Indonesia

*Corresponding Email: endanglestari@pipmakassar.ac.id

Abstract. Navigation instruments such as GPS, Radar, and ECDIS require substantial investment and continuous maintenance, which limits their availability for routine hands-on practice in maritime training. As a result, cadets may have fewer opportunities to experience learning conditions that closely resemble real operational environments. This study, conducted at the Merchant Marine Polytechnic of Makassar, aimed to develop an Augmented Reality (AR)-based learning application that visualizes ten essential ship navigation instruments: GPS, Radar, ECDIS, AIS, Gyrocompass, Echo Sounder, Autopilot, Speed Log, VHF Radio, and NAVTEX. The development followed the Multimedia Development Life Cycle (MDLC) model, including 3D object creation, marker integration, and Android application development using Unity and Vuforia. The feasibility of the application was evaluated through expert validation and field testing involving 115 cadets. Expert evaluation showed that functionality, usability, and reliability met the “Good” to “Very Good” categories, with an overall score of 84%. Cadet trials also indicated consistently positive responses, particularly in conceptual understanding, learning motivation, and ease of use, with one minor issue related to longer scanning time for a marker. Overall, the findings suggest that AR Marine NavTool is feasible for use in maritime vocational education and can serve as a preparatory learning layer that supports more structured progression to hands-on practice through accessible and interactive visualization of navigation instruments.

Keywords: Augmented Reality, Learning Media, Maritime Education, Navigation Instruments, Vocational Education

1 Introduction

The rapid development of digital technology has transformed various educational fields, including maritime vocational training. One of the persistent challenges in maritime education is the limited availability of physical navigation equipment that

cadets can use for practice. Instruments such as GPS, Radar, ECDIS, and Gyrocompass are costly to procure and maintain, and access to them during training is often limited. These limitations reduce opportunities for cadets to engage in meaningful hands-on learning, even though vocational education strongly emphasizes skill mastery that reflects actual industry conditions [1] [2].

Maritime vocational education requires repetitive practice with ship navigation instruments to build operational competence and safety awareness. However, access to real navigation instruments is frequently constrained by the limited number of laboratory units, high maintenance costs, scheduling constraints, and the risk of improper handling by novice cadets. These limitations may reduce practice opportunities and create unequal learning experiences, while safety-critical competencies still must be developed through structured training. Augmented Reality (AR) offers a controlled, repeatable, and risk-free learning environment that enables cadets to visualize components and operational procedures before interacting with real equipment, thereby supporting safer and more efficient training [3].

To address these limitations while maintaining learning authenticity and safety, an instructional technology that enables repeated practice without direct exposure to equipment risk is needed. Augmented Reality (AR) offers an alternative solution that can address these constraints by enabling digital visualization of navigation instruments through handheld devices. With AR, learners can interact with three-dimensional representations of equipment and explore their components in a more flexible and low-risk environment [4][5]. In maritime learning contexts, AR is particularly relevant because cadets must understand navigation tools clearly before operating them in real situations. In this study, the AR media is designed to support learning outcomes at three levels: cognitive understanding of instrument functions, procedural knowledge of basic operation steps, and situational awareness in interpreting navigation information for safe decision-making. Several studies have shown that AR-based systems can enhance situation awareness, reduce head-down time, and support decision-making processes on the ship's bridge [6][7][6][8]. These findings reinforce the potential of AR not only as a visualization tool but also as a medium that strengthens safety-oriented learning.

This study aligns AR learning media development with fundamental principles of vocational education: authenticity (learning tasks mirror real bridge operations), industry relevance (content reflects instruments commonly required in maritime practice), and competency-based learning (learning activities are designed to support observable competencies such as recognizing instrument functions, following operational procedures, and interpreting navigation information for decision support). In this context, AR is positioned not merely as visualization technology, but as an instructional strategy to strengthen work-oriented competence development through guided practice and structured feedback [9].

The application of AR in this research is grounded in experiential learning and simulation-based learning, where learners build understanding through guided experience, reflection, and re-application in practice. AR also supports the cognitive theory of multimedia learning, emphasizing the meaningful integration of visual representations and concise explanations to reduce cognitive overload and strengthen conceptual

transfer. These perspectives are particularly relevant for maritime training because navigation instrument operation requires both conceptual understanding and procedural fluency in safety-critical situations.

In Indonesia, research on AR-based instructional media has grown steadily in recent years. [10] demonstrated that AR use in virtual laboratories can improve productive learning outcomes, while other studies have reported gains in student motivation, engagement, and conceptual understanding across various disciplines from ethnomathematics to medical education [11][12][13]. In addition, AR applications in information technology education have been found to increase learner interest and contribute positively to learning quality [14][15][16]. Overall, these studies suggest that AR integration in vocational education provides a more authentic and immersive learning experience that aligns with contemporary industrial needs and digital learning trends [17][18].

Although AR has been widely explored in educational settings, studies that specifically develop AR media for ship navigation instruments and explicitly link the content to competency development and safety-oriented training outcomes in the Indonesian maritime higher vocational context remain limited. Prior works in maritime education often emphasize general AR/VR engagement or focus on single topics, while the need for structured learning media covering multiple bridge instruments and competency mapping is still under-addressed. Therefore, the novelty of this study lies in: (1) developing AR-based learning media for a defined set of navigation instruments, (2) mapping the media features to vocational competency development (cognitive, procedural, and situational awareness aspects), (3) positioning AR as a preparatory learning layer to reduce risk before hands-on practice, and (4) discussing feasibility for integration into maritime curricula.

Based on this rationale, the purpose of this study is to develop and evaluate an AR-based learning application for ship navigation instruments at the Merchant Marine Polytechnic of Makassar. The study contributes by providing: (1) a structured AR learning application design for key bridge instruments, (2) an evaluation of media quality using recognized software quality dimensions, and (3) empirical user feedback from cadets to inform practical implementation in maritime vocational curricula. This contribution is expected to support safer and more scalable learning preparation prior to hands-on training sessions.

2 Method

This study employed a Research and Development (R&D) approach using the Multimedia Development Life Cycle (MDLC) model. The MDLC framework was selected because it provides a clear and systematic structure for multimedia-based product development, particularly for applications that combine visual, interactive, and technical components. The model consists of six sequential phases: concept, design, material collecting, assembly, testing, and distribution, which together guide the process of transforming initial ideas into a functional learning product.



Fig. 1. Stages of the MDLC

The research was carried out at the Merchant Marine Polytechnic of Makassar with 115 cadets participating as respondents in the product trial. Their involvement was based on their direct engagement with navigation-related coursework, ensuring that the feedback obtained reflected real user needs within maritime vocational learning. Thus, the evaluation results are expected to represent the practical learning context at the institution.

The development process began with the concept phase, which focused on defining the objective of creating AR-based learning media capable of visualizing ten primary navigation instruments. The selection of these ten instruments was based on both pedagogical and professional considerations. Pedagogically, the instruments represent core navigation functions that must be understood by cadets: positioning, route monitoring, situational awareness, collision-avoidance support, and bridge communication. Professionally, these instruments are commonly introduced in navigation-related courses and bridge operation training, making them highly relevant to industry-oriented competency development. Therefore, focusing the AR content on these instruments ensures that the learning media remains authentic, curriculum-relevant, and aligned with competency-based maritime vocational training.

In the design phase, the application's interface was structured by preparing four main menus: Scan AR, QR-Code, Information, and Exit. The material collecting phase involved gathering both technical and visual data related to the ten navigation instruments as the basis for developing three-dimensional objects.

In addition to visualization, the AR learning media was designed to support three levels of learning outcomes: (1) cognitive understanding, enabling cadets to recognize instrument components and functions; (2) procedural knowledge, supporting basic operational sequences through guided interaction; and (3) situational awareness, encouraging cadets to interpret instrument information as part of safe navigation decision-making. These outcome targets were used to frame the development features and to guide the evaluation indicators in both expert validation and cadet trials.

During the assembly phase, the collected materials were processed into 3D models using Blender, followed by marker integration through Vuforia, and the compilation of the application in Unity for Android-based use. These activities ensured that each

instrument could be displayed interactively when scanned by a mobile device. The application was intentionally developed for Android smartphones to improve practical feasibility and accessibility in classroom settings. This platform choice supports scalability because cadets can use their own devices for repeated practice, and instructors can integrate the AR activity as a pre-lab module prior to limited hands-on sessions in the navigation laboratory.

The testing phase included two complementary evaluation methods. First, black-box testing was conducted to examine whether each feature and function of the application operated correctly. Second, validation by a media expert was carried out to assess the feasibility of the product in terms of functionality, usability, and reliability using the ISO 9126 standard. The questionnaire content was reviewed together with the media expert validation process to ensure clarity, relevance, and alignment with the evaluation indicators. In addition to expert validation, the application was tested with 115 end users (cadets) using a structured questionnaire. The questionnaire consisted of two parts: (1) ten general items capturing perceived ease of use, engagement, motivation, and perceived learning support; and (2) ISO 9126-based indicators (functionality, usability, and reliability) to obtain a more comprehensive perspective on software quality from end users.

The collected data were analyzed using descriptive statistics by calculating mean scores and percentages for each indicator. The results were then categorized into five rating levels “Very Good,” “Good,” “Fair,” “Poor,” and “Very Poor” referring to the assessment criteria proposed. Through this analysis, a clear overview of the feasibility and effectiveness of the developed AR based learning media was obtained from both expert and user perspectives.

3 Result and Discussion

The research product developed is the AR Marine NavTool application, an Augmented Reality-based learning media that visualizes ten ship navigation instruments. The application was built using Unity, Vuforia, and Blender, and then packaged as an Android application. Its interface presents four main menus: Scan AR, QR-Code, Information, and Exit. The simple interface design makes the application easy for cadets to understand and operate without requiring additional training.

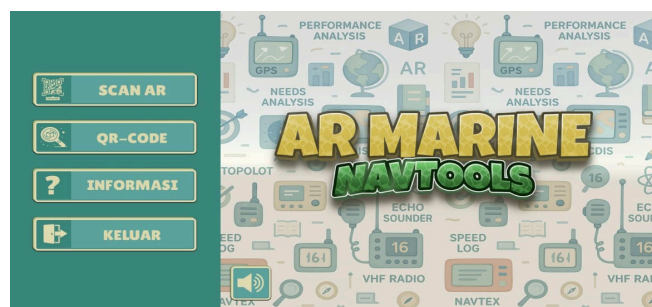


Fig. 2. Main Interface of the AR Marine NavTool Application

When the *Scan AR* menu is used, the smartphone camera is directed at the prepared markers. Each marker represents a specific navigation instrument, such as GPS or Radar. The scanning process displays a three-dimensional object of the instrument, complete with its visual details. Users can also access the *Information* menu to read a description of the instrument’s function and listen to an audio explanation. For example, the GPS marker generates a 3D model of a GPS receiver along with an explanation of its function as a device that accurately determines the ship’s latitude and longitude position.

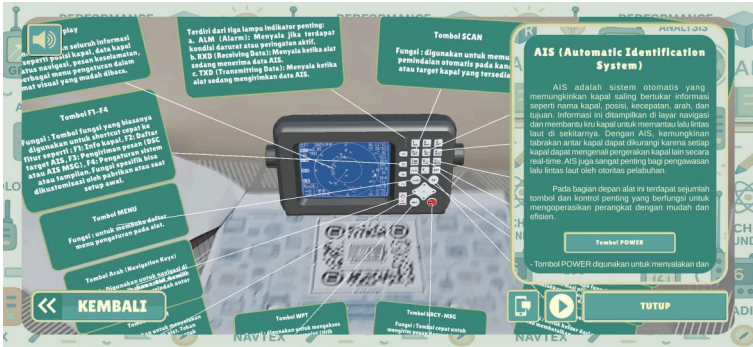


Fig. 3. Example of AR Marker Display Generating a 3D Object

The validation results from the media expert indicated that the application met the feasibility criteria for functionality, usability, and reliability based on the ISO 9126 standard. For functionality, the average score reached 86%, categorized as “Very Good.” For usability, the score was 82%, or “Good,” confirming that the application interface is easy to use and understand. Meanwhile, for reliability, the application obtained a score of 84%, also categorized as “Good,” as the system ran stably despite a minor technical note regarding slightly longer scanning times for certain QR codes. Overall, the average validation score from the media expert was 84%, indicating that the application is feasible to be used as a learning medium.

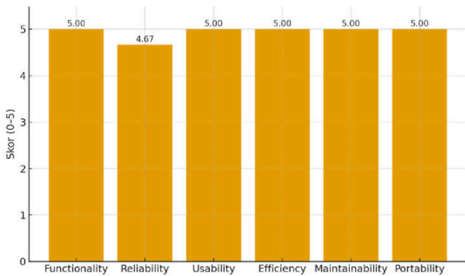


Fig. 4. Graph of Media Expert Validation Results Based on ISO 9126 Aspects

Field trials were conducted with 115 cadets of the Merchant Marine Polytechnic of Makassar using a general instrument consisting of ten statements. The analysis

showed that for indicator P1 (conceptual understanding), 67.8% of cadets rated the media as “Very Good,” 24.3% as “Good,” and only 7.9% as “Fair.” For P2 (learning interest), 71.3% of cadets rated “Very Good” and 20.9% rated “Good.” For P3 (engagement), 28.7% of cadets rated “Very Good” and 62.6% rated “Good.” For P4 (ease of use), 75.6% of cadets rated “Very Good” and 17.4% rated “Good.”

The subsequent indicators also showed positive results. For P5 (relevance), 64.3% of cadets rated the media as “Good” and 25.2% as “Very Good.” For P6 (self-confidence), 61.7% rated it “Good” and 27.8% “Very Good.” For P7 (learning motivation), 65.2% rated “Good” and 24.3% “Very Good.” For P8 (recommendation for use), 68.7% rated “Good” and 20.9% “Very Good.” For P9 (satisfaction), 63.5% rated “Good” and 26.1% “Very Good.” Finally, for P10 (overall benefits), 66.1% rated “Good” and 21.7% “Very Good.” These data indicate that the average cadet responses consistently fell within the “Good to Very Good” categories, showing a positive distribution overall.

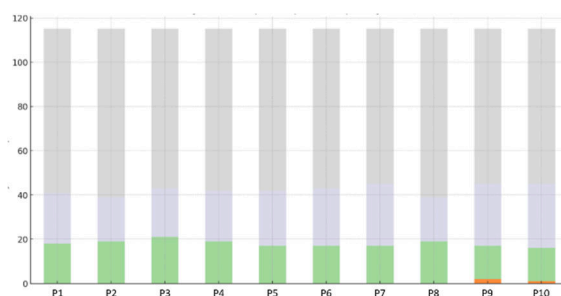


Fig. 5. Graph of Cadet Responses to the General Instrument (P1–P10)

In addition to the general instrument, cadets were also asked to evaluate the application based on the ISO 9126 aspects. The analysis results showed that for functionality, the average respondent score was 83% (“Good”). For usability, the average score reached 81% (“Good”), while for reliability the score was 84% (“Very Good”). The overall average score across the three aspects was 82.7%, confirming that cadets considered the application to be highly feasible for use in learning.

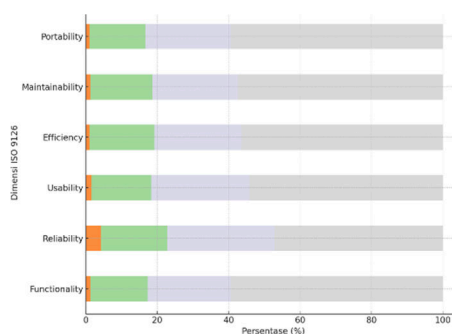


Fig. 6. Graph of Cadet Evaluation of the Application Based on ISO 9126 Aspects

Overall, the media expert validation and cadet trials provide consistent evidence that AR Marine NavTool meets technical feasibility and learning-support criteria. Expert validation produced an overall score of 84% across functionality, usability, and reliability, while cadet evaluations showed predominantly “Good” to “Very Good” responses on both the general instrument (P1–P10) and ISO 9126-based indicators (overall average 82.7%). These results suggest that the application is feasible for learning use and supports conceptual understanding, engagement, and motivation, with scanning optimization identified as a practical area for future improvement.

From a safety and risk-reduction perspective, AR Marine NavTool functions as a preparatory learning layer before cadets interact with real navigation instruments. By enabling repeated exploration of instrument components, menu structures, and basic operating logic in a controlled environment, the application can reduce trial-and-error behaviors during limited laboratory sessions and minimize the likelihood of incorrect operational steps by novice users. This approach supports safer learning progression because cadets enter hands-on practice with clearer conceptual readiness and procedural familiarity, which is particularly important in maritime training where incorrect instrument interpretation may contribute to operational risk. Therefore, AR-based learning is positioned as a low-risk rehearsal strategy that complements, rather than replaces, hands-on practice.

In terms of practical implementation, the consistently positive usability and reliability scores from both expert validation and cadet evaluation indicate that the application can be adopted without extensive additional training. The Android-based platform supports scalability because cadets can access the learning media using commonly available devices, allowing repeated practice outside scheduled laboratory time. Instructors may integrate the application as a pre-lab activity (e.g., introduction and guided exploration) and as a reinforcement tool after laboratory sessions, thereby optimizing limited access to physical instruments while maintaining curriculum alignment.

These findings are consistent with the results [4], who conducted a systematic review on the application of AR in vocational education and concluded that the technology enhances both conceptual understanding and student engagement. Similarly [5], emphasized through a meta-analysis that AR and mixed reality significantly impact the quality of vocational learning. In the context of maritime navigation, [19] demonstrated that the use of AR in multi-user collaboration improves situation awareness on ship bridges. This study is also in line with the findings of [6], who reported that AR reduces operators’ head-down time and increases attention to the navigational environment. Thus, the integration of AR Marine NavTool into navigation learning aligns with international studies that highlight the effectiveness of AR in both maritime and vocational contexts.

From an interface design perspective, the simplicity and clarity of the AR Marine NavTool interface are in line with the AR bridge interface design framework introduced by [7]. A clean and straightforward layout generally helps users interact more easily with digital objects, particularly when engaging with AR-based learning content. This is also reflected in the observations of [20], who highlighted that user experience plays a crucial role in the development of AR interfaces for navigation simula-

tors. In this regard, the accessible design of AR Marine NavTool provides cadets with a more intuitive entry point to explore navigation instruments, supporting key principles for effective AR implementation in maritime learning environments.

Within the Indonesian context, the results of this study support earlier findings by [1], who showed that integrating AR into vocational education can strengthen students' practical skill development. A similar trend was reported by [2], whose AR-based media for automotive power transmission systems improved learners' understanding of technical concepts. [10] also demonstrated the usefulness of AR in virtual laboratory settings to enhance productive learning. These studies are consistent with the positive responses from cadets in this research, indicating that AR-based media can offer meaningful support for practical learning across different vocational domains.

The increase in cadets' learning motivation observed in this study is in line with the findings of [11], who reported that AR-based ethnomathematics media could enhance students' motivation to engage with learning materials. Similar patterns were also noted by [12], who found that AR helped improve learning satisfaction among medical students studying heart anatomy. [13] further emphasized the value of AR/VR technology in supporting clinical skills during the pandemic, demonstrating the broader relevance of immersive media across various educational fields. Taken together, these studies support the results of the present research, suggesting that AR can serve as an effective approach for strengthening practical learning experiences in vocational settings.

The findings have implications for maritime vocational education policy and practice. For institutions, AR-based learning media can be positioned as a cost-effective strategy to expand access to training resources when physical instruments are limited, supporting digital transformation in higher vocational education. For instructors, AR Marine NavTool can standardize introductory instruction, reduce time spent on basic familiarization during laboratory sessions, and provide a structured pathway toward competency-based learning. For policymakers and institutional leaders, supporting the development and adoption of scalable digital learning media such as AR may strengthen the quality and safety orientation of maritime training while maintaining alignment with industry needs and curriculum requirements.

This study also contributes a new perspective by applying AR specifically to ship navigation instruments, an area that has received relatively little attention in previous research. While many earlier studies focused on AR applications in science, medicine, or general engineering, the present research highlights its potential within maritime vocational learning [18], for example, examined AR limitations in navigation primarily from a technical standpoint, whereas this study places greater emphasis on pedagogical use for cadets. Likewise, [17] explored AR/VR for navigation safety in inland waterways, while the current study demonstrates its application directly in maritime training. These distinctions illustrate how the present research extends existing knowledge by introducing AR as a tool for supporting the mastery of core competencies required of maritime cadets in Indonesia.

4 Conclusion

This study developed AR Marine NavTool as an AR-based learning application that visualizes ten core ship navigation instruments. The development process followed the six stages of the MDLC model, enabling the creation of functional 3D representations and an interactive mobile application that supports cadets in understanding instrument components and functions without relying solely on physical equipment.

Expert validation indicated that the application meets feasibility criteria in terms of functionality, usability, and reliability, with an overall score of 84%. Field trials involving 115 cadets further reinforced the feasibility of the application, with most responses falling within the “Good” to “Very Good” categories across indicators such as conceptual understanding, motivation, ease of use, and overall learning experience. A minor technical issue related to scanning responsiveness for one marker was identified, but it did not affect the overall functionality and can be addressed in future updates.

From a maritime training perspective, AR Marine NavTool can be used as a preparatory learning layer that supports safer learning progression by reducing trial-and-error during limited hands-on laboratory sessions. Practically, the application offers a scalable alternative for institutions with constrained access to navigation instruments, and it can support instructors in standardizing introductory instruction and strengthening competency-based learning implementation. Future development may focus on optimizing scanning responsiveness, expanding learning content, and incorporating more interactive simulations to further enhance engagement and instructional value.

References

1. Supriyanto S, Joshua Q, Abdullah AG, Tettehfi EO, Ramdani SD. Application of augmented reality in vocational education: A systematic literature review. *Jurnal Pendidikan Vokasi*. 2023;13(2):205–13. doi:10.21831/jpv.v13i2.54280
2. Dani DF, Ramdani SD, Supriyatna D. Developing augmented reality on differential system, competency system, and power transfer in vocational education. *Jurnal Pendidikan Vokasi*. 2022;12(2):152–67. doi:10.21831/jpv.v12i2.48804
3. Rijal A, Rahman A, Pratama R. Pengembangan aplikasi augmented reality untuk memahami konsep kelistrikan (UPARUPA). *Jurnal Pendidikan dan Teknologi Indonesia*. 2025;5(3). doi:10.52434/jpti.v5i3.12345
4. Chiang FK, Shang X, Qiao L. Augmented reality in vocational training: A systematic review of research and applications. *Comput Human Behav*. 2022;129:107125. doi:10.1016/j.chb.2021.107125
5. Bødding M, Scheiter K, Schneider S. The influence of mixed reality on students in vocational education and training: A meta-analysis. *Virtual Real*. 2025. doi:10.1007/s10055-025-01118-z
6. Houweling KP, van den Oever F, Rossetti AM. Augmented reality can improve operator situation awareness while limiting head-down time. *Appl Ergon*. 2024;117. doi:10.1016/j.apergo.2024.104145
7. Nordby K, Fostad A, Langaas K. A user-interface design framework for augmented reality on ship bridges. *J Mar Sci Eng*. 2024;12(3):505. doi:10.3390/jmse12030505

8. Laera F, Nocente A, Gamberini L. An augmented reality head-mounted sailing interface: A comparative study in a virtual reality simulator. *Virtual Real.* 2023. doi:10.1007/s10055-022-00706-7
9. Houweling KP, van den Oever F, Rossetti AM. An approach for measuring the effects of augmented reality on human performance in maritime navigation. In: *Proceedings of the Human Factors and Ergonomics Society Annual Meeting.* 2023. doi:10.1177/21695067231193647
10. Herlandy PB. Virtual laboratory application using augmented reality for vocational productive learning. *Jurnal Pendidikan Teknologi dan Kejuruan.* 2019;25(1):45–56. doi:10.21831/jptk.v25i1.26504
11. Umri BK, Cahyono A, Rachman A. Pengembangan media pembelajaran etnomatematika berbasis augmented reality berbasis candi-candi Nusantara. *Jurnal Teknologi Informasi dan Ilmu Komputer.* 2025;12(2). doi:10.1234/jtiik.9330
12. Nurrokhmanti H, Wibowo FS, Wardhani R. Augmented reality of heart in teaching gross anatomy: A lesson learned. *Jurnal Pendidikan Kedokteran Indonesia.* 2022;11(4):419–27. doi:10.22146/jpki.69741
13. Setiawan IP, Leatemia LD, Prihatanto FSI. Facilitating clinical skill training during and following the COVID-19 pandemic. *Jurnal Pendidikan Kedokteran Indonesia.* 2022;11(4):436–44. doi:10.22146/jpki.73683
14. Kurniawan YI, Kusuma AFS. Aplikasi augmented reality untuk pembelajaran salat bagi siswa sekolah dasar. *Jurnal Teknologi Informasi dan Ilmu Komputer.* 2021;8(1):7–14. doi:10.25126/jtiik.0812182
15. Afirianto T, Wardhono WS, Pelealu BN, Akbar MA. Media pembelajaran calistung berbasis augmented reality untuk menarik minat belajar anak. *Jurnal Teknologi Informasi dan Ilmu Komputer.* 2021;8(2):43–50. doi:10.25126/jtiik.2021824510
16. Pujakesuma D, Wibawa AP, Putra DA. Analisis pengaruh media pembelajaran augmented reality terhadap hasil belajar dan retensi siswa. *Jurnal Teknologi Informasi dan Ilmu Komputer.* 2025;12(2). doi:10.1234/jtiik.9683
17. Templin T, Popielarczyk D, Gryszko M. Augmented reality in navigation in inland and coastal waters. *Remote Sens (Basel).* 2022;14(6):1520. doi:10.3390/rs14061520
18. Butkiewicz T, Wallace R, Ware C. Evaluation of the effects of field of view in augmented reality for maritime navigation. In: *Proceedings of SPIE.* 2020. doi:10.1117/12.2546605
19. van den Oever F, Houweling KP, Soldaat L, Rossetti AM. A field study of multi-user augmented reality to facilitate collaborative ship navigation. *Ergonomics.* 2025. doi:10.1080/00140139.2025.2519874
20. Laera F, Gamberini L, Spagnolli A. A systematic review of the effectiveness of data visualization in maritime operations. *Journal of Navigation.* 2021;74(6):1310–34. doi:10.1017/S0373463321000257