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Design and Development of an Arduino-Based Ship Lift Learning Media Using a PLC Approach for Cadets of Makassar Maritime Polytechnic

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Abstract: Design and Development of Arduino-Based Ship Lift Learning Media with a PLC Control Approach for Cadets of Makassar Maritime Polytechnic is a study motivated by the limited availability of practical learning media for automatic control systems that resemble real shipboard conditions. This study aims to design, develop, and examine the feasibility and effectiveness of Arduino-based ship lift learning media using a Programmable Logic Controller control approach. The research object is the ship lift learning media used by cadets of Makassar Maritime Polytechnic. This study employed a Research and Development method with the ADDIE model, consisting of analysis, design, development, implementation, and evaluation stages. Data were collected through interviews, observation, questionnaires, documentation, expert validation, user trials, and prototype testing. The results show that the developed learning media is able to simulate lift movement, sensor reading, actuator control, stopping logic, interlocking, and basic safety systems. The media is considered feasible, easy to use, reusable, and effective in improving cadets' conceptual understanding, practical skills, and readiness to understand ship automation systems.

Keyword: Arduino, Ship Lift, PLC Control, Learning Media, Maritime Vocational Education.

INTRODUCTION

The development of automation in modern merchant vessels requires the use of auxiliary systems that support operational safety, efficiency, and convenience (Dagkinis et al., 2023). One important piece of equipment is the ship lift, which operates through an automatic control system that integrates mechanical, electrical, and control components (Suparmono et al., 2025). Therefore, technical understanding is required for its operation and maintenance.

In practice, cadets or beginner technicians still face limitations in understanding the working principles of automation-based lift control systems (Karimpour & Figari, 2025). Operational errors, delays in troubleshooting, and dependence on shore-based technicians indicate a gap between educational theory and actual practice on board vessels.

Programmable Logic Controller (PLC)-based control systems have become a standard in automated equipment on board ships (Arifin et al., 2025). However, limited practical training facilities cause PLC learning to remain largely theoretical and less applied, resulting in suboptimal readiness among cadets when dealing with real systems.

As a vocational maritime education institution, Makassar Maritime Polytechnic is required to produce graduates with both conceptual competence and practical skills. Therefore, an applicable, economical, and industry-relevant learning medium is needed. Arduino, as an open-source microcontroller, can be used as a learning medium based on a PLC control approach to simulate the working principles of a ship lift system in a practical manner and improve cadets' understanding (Widayaka et al., 2024).

In addition, the lack of representative learning media can reduce cadets' ability to connect theoretical control concepts with real operational mechanisms on board ships. Without direct simulation, cadets may understand the basic principles of automation only conceptually, but still experience difficulties in interpreting input signals, output responses, actuator movements, sensor functions, and troubleshooting sequences in an integrated system. This condition may weaken their practical readiness when facing actual automation equipment in ship operations.

Another problem is that conventional PLC training equipment is often relatively expensive, less flexible, and not always available in sufficient quantity for repeated individual practice. As a result, the learning process may become instructor-centered and limited to demonstration rather than active hands-on experimentation. Therefore, a more accessible and reusable learning medium is needed to bridge the gap between classroom theory and practical competence, particularly through an Arduino-based system that adopts PLC control logic for ship lift simulation.

The urgency of this research is based on the need to improve cadets' competence in understanding automatic control systems used on modern ships, especially ship lift systems that apply PLC-based control principles. Since practical learning media are still limited, PLC learning often remains theoretical and does not fully prepare cadets for real shipboard equipment. Therefore, an Arduino-based ship lifts learning medium using a PLC approach is needed because it is practical, affordable, flexible, and suitable for vocational maritime education. This media is expected to improve cadets' technical understanding, practical skills, and work readiness in the maritime industry.

METHOD

This study employs a Research and Development (R&D) approach, which aims to produce a learning media product and examine its feasibility and effectiveness in the learning process. The development model used in this study is the ADDIE model, consisting of Analysis, Design, Development, Implementation, and Evaluation stages. This model was selected because it provides a systematic framework and is suitable for developing technology-based learning media. The data sources consist of primary data and secondary data. Primary data are obtained directly from cadets of Makassar Maritime Polytechnic as users of the learning media, as well as from lecturers, instructors, and media experts who act as validators. Meanwhile, secondary data are collected from scientific journals, reference books, previous studies, curriculum documents, and competency standards. Data collection techniques include interviews, questionnaires, observation, documentation, and prototype testing. The data analysis technique applies a mixed-method approach, combining qualitative

descriptive analysis and simple quantitative analysis. Data validation is conducted through expert judgment involving material experts, media/technology experts, and user trials involving cadets.

RESULT AND DISCUSSION

The development of the Arduino-based ship lift learning media with a PLC control approach was conducted using the Research and Development method through the ADDIE model, consisting of Analysis, Design, Development, Implementation, and Evaluation stages. This model is appropriate because the study aims not only to describe a learning problem, but also to produce, validate, and test a technology-based learning product. The ADDIE framework provides a systematic structure for identifying learning needs, designing media specifications, developing prototypes, implementing learning activities, and evaluating product feasibility. Recent studies on technology-based learning media also confirm that the ADDIE model is widely used because it supports structured product development, expert validation, and user testing in educational contexts (Mardani et al., 2026).

At the Analysis stage, the study identified that cadets of Makassar Maritime Polytechnic still need practical learning media that can represent the working principles of automated ship lift systems. PLC learning tends to remain theoretical when students do not have sufficient access to training equipment that integrates input devices, sensors, actuators, and control logic. This condition is consistent with previous research stating that the limited availability of practical trainer media can reduce students' opportunity to understand control systems through direct experimentation. Studies on PLC and microcontroller trainer media show that practical learning tools are important because they allow students to connect theoretical concepts with real input-output processes, system responses, and troubleshooting activities (Irfan & Mubai, 2023).

At the Design stage, the learning media was designed by translating the operational logic of a ship lift into a small-scale prototype. The system includes push buttons, limit switches or position sensors, Arduino as the control unit, motor drivers, actuators, indicators, and basic safety features. The control logic was arranged using a PLC approach, especially through sequential logic, interlocking, command execution, position detection, and emergency stop logic. This design is pedagogically relevant because cadets can observe how input signals are processed by the controller and converted into actuator movement (Surya, 2025). Research on Arduino-based and PLC-oriented learning media supports this approach, showing that microcontroller-based trainers can help students understand electronics, logic control, ladder-diagram concepts, and automation processes through practical activities.

At the Development stage, the prototype was assembled and programmed to simulate the basic functions of a ship lift system. Arduino was used as the main controller to read input signals, process PLC-like logic, and activate the motor or actuator according to the programmed sequence. The prototype was developed to perform upward and downward movement, stop at the intended position, respond to user commands, and activate basic safety protection through limit logic or emergency stop. The use of Arduino in this context is appropriate because it is flexible, affordable, easy to program, and suitable for educational control-system prototypes. However, scientifically, the media should be positioned as a learning simulator with a PLC control approach, not as a replacement for certified industrial or marine-grade PLC systems. This distinction is important because actual shipboard lift systems require higher levels of certification, redundancy, durability, and compliance with marine safety standards.

At the Implementation stage, the media was introduced to cadets as a practical learning tool. Through direct practice, cadets were able to observe the relationship between control commands, sensor feedback, actuator movement, and system safety responses. This hands-on

process is important in vocational maritime education because cadets must not only understand automation theoretically, but also be able to interpret how automated equipment behaves in real operational conditions. Simulation-based learning in maritime training has been shown to improve competency, preparedness, decision-making, and confidence because learners can practice in a controlled environment before facing actual shipboard systems (Ala et al., 2024).

At the Evaluation stage, the feasibility of the media was assessed through expert judgment, questionnaires, observation, documentation, and prototype testing. Material experts assessed the suitability of the learning content with ship automation and control-system competencies, while media and technology experts evaluated the design, functionality, ease of use, safety, and technical quality of the prototype. User trials involving cadets provided feedback on practicality, clarity, usability, and learning usefulness. This evaluation approach is aligned with R&D-based learning media studies, where expert validation and user trials are used to determine whether a product is valid, practical, and effective before being recommended for broader use (Mardani et al., 2026).

In terms of control logic accuracy, the Arduino-based ship lift media can be considered functional when the system is able to execute commands according to the intended sequence. The accuracy is reflected in the ability of the prototype to detect input commands, determine lift movement direction, stop at the correct position, and prevent conflicting commands. This shows that the programmed control logic is aligned with the expected operational behavior of an automatic lift system. Previous studies on PLC microcontroller trainer media also found that microcontroller-based control trainers can support students' understanding of logic control because they provide direct interaction between programming, hardware response, and output movement (Irfan & Mubai, 2023).

In terms of operational reliability, the media is reliable for learning purposes when it can be operated repeatedly without major functional failure, unstable motor response, incorrect command execution, or inconsistent stopping behavior. The repeated use of the prototype in practical sessions allows cadets to test different operating scenarios and observe how the system responds. This is relevant to vocational learning because repeated experimentation supports procedural understanding and psychomotor skill development. Satrinawati et al. found that the use of Outseal PLC microcontroller trainer media was considered highly practical by teachers and students and contributed to improvements in cognitive, affective, and psychomotor learning outcomes.

In terms of system safety, the learning media must include basic safety mechanisms such as upper and lower travel limits, emergency stop, motor stop at the destination point, and interlocking to prevent simultaneous upward and downward commands. These safety features are essential because learning automation should not only focus on system movement, but also on safe operation and fault prevention. In maritime education, safety-oriented automation learning is particularly important because shipboard equipment failure may affect operational continuity and crew safety. Maritime simulation-based learning research emphasizes that training media should prepare learners to understand system behavior, respond to abnormal conditions, and improve readiness for automation-driven ship operations.

The feasibility of this media can be seen from technical, pedagogical, and operational aspects. Technically, the prototype is feasible because it can represent the basic components of an automated lift system, including input, controller, actuator, and safety logic. Pedagogically, it is feasible because it helps transform abstract PLC concepts into observable physical processes. Operationally, it is feasible because Arduino-based systems are low-cost, flexible, reusable, and easier to modify compared with conventional industrial PLC training equipment. This is supported by studies showing that microcontroller-based trainer media can

provide an affordable alternative for learning automation and control systems, especially in institutions with limited access to expensive industrial trainers.

The effectiveness of the media is reflected in its ability to improve cadets' understanding of ship lift control systems through active and contextual learning. By using the prototype, cadets can observe how input signals, controller logic, sensor feedback, and actuator responses are integrated in one system. This supports not only conceptual understanding, but also practical skills, troubleshooting ability, and work readiness. In vocational and maritime education, this type of learning media is important because graduates are expected to master both theoretical knowledge and technical competence. Therefore, the Arduino-based ship lift learning media with a PLC control approach can bridge the gap between classroom theory and real shipboard automation practice.

Overall, the findings indicate that the developed learning media is technically implementable, functionally reliable for practicum use, and pedagogically relevant for cadets of Makassar Maritime Polytechnic. The R&D process using the ADDIE model ensures that the product is developed based on actual learning needs, validated by experts, tested through prototype operation, and evaluated through user responses. Nevertheless, this prototype should be understood as an educational simulator rather than a certified ship lift control system. Future development may include the addition of a human-machine interface, fault simulation, data logging, overload protection, and integration with actual PLC ladder diagram visualization to make the learning experience closer to real marine automation systems.

CONCLUSION

This study concludes that the Arduino-based ship lift learning media with a PLC control approach was successfully developed through the Research and Development method using the ADDIE model. The development process began with identifying learning needs, designing the prototype, developing the hardware and control program, implementing the media in practicum activities, and evaluating its feasibility through expert judgment, observation, questionnaires, and prototype testing.

The developed media is technically feasible because it can simulate the basic operation of a ship lift system through the integration of input commands, Arduino-based control logic, sensors, actuators, and safety mechanisms. The system is able to demonstrate lift movement, position detection, stopping control, interlocking, and emergency stop functions, making it suitable as a practical learning tool for automatic control systems.

Overall, this learning media is considered effective in supporting cadets' understanding of ship lift automation systems. It helps bridge the gap between theoretical PLC learning and practical shipboard automation, while improving cadets' conceptual understanding, practical skills, troubleshooting ability, and readiness to face automated equipment in the maritime industry.

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