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Development of Water Treatment HSSEC System to Support Net Zero Emissions in Maritime Vocational Education: Evidence from Politeknik Pelayaran Sumatera Barat

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Abstract

This study aims to describe the development process of the Water Treatment HSSEC as an initiative to support the achievement of Net Zero Emission at Politeknik Pelayaran Sumatera Barat. The study employed a Research and Development (R&D) method using the ADDIE development model, which was limited to the analysis and design phases. The analysis phase included curriculum analysis based on the IMO Model Course 7.04 Officer in Charge of an Engineering Watch using an observation checklist, lecturers' needs analysis through semi-structured interviews, and students' needs analysis using a questionnaire covering the dimensions of necessity, lack, and want. The findings revealed that the existing curriculum has not comprehensively integrated Water Treatment HSSEC into the learning process, practical learning media and instructional materials remain limited, and both lecturers and students expressed a strong need for learning media that support Green Shipping and Net Zero Emission. The design phase produced a Water Treatment HSSEC prototype consisting of a multi-stage filtration system, water circulation mechanism, concrete filtration tank, and a manual book containing the conceptual framework, system architecture, filtration mechanism, standard operating procedures, maintenance guidelines, and occupational safety procedures. The results indicate that the proposed Water Treatment HSSEC has been designed in accordance with user needs, the characteristics of maritime vocational education, and the demands of the shipping industry, thereby demonstrating its potential to serve as a Teaching Factory that enhances students' competencies while supporting the implementation of Net Zero Emission at Politeknik Pelayaran Sumatera Barat.

Keywords: Water Treatment HSSEC, Green Shipping, Net Zero Emission, Teaching Factory.

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INTRODUCTION

Net zero emissions refer to a condition in which the amount of greenhouse gases released into the atmosphere is balanced by the amount removed or absorbed from the atmosphere (Satola et al., 2021). According to the United Nations Framework Convention on Climate Change (UNFCCC), net zero signifies a state in which human activities have no net impact on the climate system because emissions are substantially reduced and any remaining emissions are offset through carbon removal (Tan et al., 2022). This objective has become increasingly urgent, as the

Intergovernmental Panel on Climate Change (IPCC) emphasizes that limiting global warming to 1.5°C requires achieving global net-zero CO_2 emissions by approximately 2050 (Bossy et al., 2024). Reaching this target also demands substantial emission reductions during the current decade. The IPCC further highlights that this transition requires a combination of strategies, including reducing energy demand, decarbonizing electricity generation and fuels, electrifying end-use energy systems, and significantly lowering non-CO_2 emissions (Anika et al., 2022). Consequently, achieving net zero emissions has become a critical global agenda for ensuring climate sustainability and safeguarding future generations.

In Indonesia, the net zero emissions agenda is supported through Presidential Regulation No. 98 of 2021 concerning the Implementation of Carbon Economic Value for Achieving Nationally Determined Contributions and Greenhouse Gas Emission Control in National Development (Presiden RI, 2021). This regulation provides the legal framework for greenhouse gas emission control and the implementation of carbon pricing mechanisms to strengthen the achievement of national climate targets (Sulistiawati & Buana, 2023). In 2024, the Ministry of Energy and Mineral Resources reaffirmed the government's commitment to achieving Net Zero Emissions (NZE) by 2060 through the expansion of renewable energy, energy conservation, and the adoption of clean technologies. In 2025, the Ministry further emphasized that Indonesia remains committed to achieving net-zero emissions by 2060 through a carefully managed transition pathway (Negara et al., 2023). The government also promotes supporting technologies, including hydrogen, Carbon Capture and Storage (CCS), and Carbon Capture, Utilization, and Storage (CCUS), as integral components of the country's low-carbon energy transition strategy (Purnami et al., 2022). These policy initiatives demonstrate Indonesia's alignment with global efforts toward emission reduction and sustainable development.

Politeknik Pelayaran Sumatera Barat has introduced the HSSEC initiative as the institutional identity for strengthening a sustainable campus. HSSEC stands for Humanist, Smart, Sustainable, and Eco-Friendly Campus (Kurniawan, 2024). According to official institutional reports, HSSEC is closely associated with the Green Innovation Campus initiative and pentahelix collaboration aimed at accelerating the achievement of net zero emissions (Ankareddy et al., 2025). Previous studies have also reported that the HSSEC program contributes to improving cadet quality management while strengthening sustainability awareness among campus stakeholders (Garay-rondero & Issa-zadeh, 2025). These findings indicate that HSSEC represents not merely an institutional slogan but also a comprehensive framework for fostering academic culture, character development, and environmental responsibility (Widiatmaja et al., 2026). Therefore, the development of the Water Treatment HSSEC system represents a practical implementation of the institution's vision of becoming a humanistic, smart, sustainable, and environmentally friendly maritime campus.

Water treatment refers to the process of removing contaminants from water to ensure that it can be safely discharged, reused, or distributed for appropriate purposes (Ribarova et al., 2024). The United States Environmental Protection Agency (EPA) emphasizes that contaminated water should be collected and adequately treated before being safely released into the environment or transferred to wastewater treatment facilities (Z. Wang et al., 2024). Recent studies have demonstrated significant technological advances in this field, Forhad et al., (2024) developed an Internet of Things (IoT)-based water treatment monitoring system equipped with real-time sensors for pH, dissolved oxygen, total dissolved solids, and temperature. Diallo et al., (2024) proposed an integrated treatment system combining granular activated carbon, powdered activated carbon (PAC)/biochar, and ultrafiltration to improve water quality while reducing membrane fouling. Likewise, Lichtmannegger et al., (2024) investigated wastewater treatment efficiency in tourism areas and highlighted the necessity of expanding and upgrading treatment systems to accommodate seasonal demand. Moretti et al., (2024) further demonstrated that Industry 4.0 technologies, smart sensors, and automation can significantly enhance the adaptability, operational efficiency, and sustainability of modern water treatment systems.

Despite these advances, existing HSSEC-related studies at Politeknik Pelayaran Sumatera Barat have primarily focused on improving cadet quality and promoting a sustainable campus culture rather than developing water treatment systems as a technical solution for campus sustainability (Mashartanto et al., 2024). Similarly, previous water treatment research has largely concentrated on water quality monitoring, filtration media integration, process automation, and operational efficiency within existing treatment systems (Fu et al., 2025). Consequently, a significant research gap remains regarding the development of a Water Treatment HSSEC system

specifically designed to support the institution's Net Zero Emissions agenda (Dawodu et al., 2022). The novelty of this study lies in the development of the Water Treatment HSSEC system using the ADDIE model to systematically explain the needs analysis and product design processes. Rather than focusing solely on the final product, this study emphasizes a structured development process that can be replicated as a sustainable campus innovation model. Accordingly, this research is expected to bridge the existing gap at the intersection of HSSEC implementation, sustainable water management, and campus decarbonization within maritime vocational education.

Based on the foregoing background, this study aims to explain the development process of the Water Treatment HSSEC system as an initiative to support the achievement of Net Zero Emissions at Politeknik Pelayaran Sumatera Barat.

METHOD

This study employed a Research and Development (R&D) approach to develop the Water Treatment HSSEC system. The development process adopted the ADDIE model, consisting of the Analysis, Design, Development, Implementation, and Evaluation phases. However, this study was limited to the Analysis and Design phases.

The Analysis phase focused on conducting a needs assessment to identify the problems and requirements that justified the development of the Water Treatment HSSEC system. The needs assessment comprised three components: (a) curriculum analysis, (b) lecturers' needs analysis, and (c) students' needs analysis. The findings from this phase served as the primary basis for designing a learning facility that addresses the identified educational needs. The Design phase included (a) defining the objectives of the product, (b) selecting the required components and materials, (c) developing the operational workflow of the system, and (d) preparing the preliminary product design and the accompanying manual book.

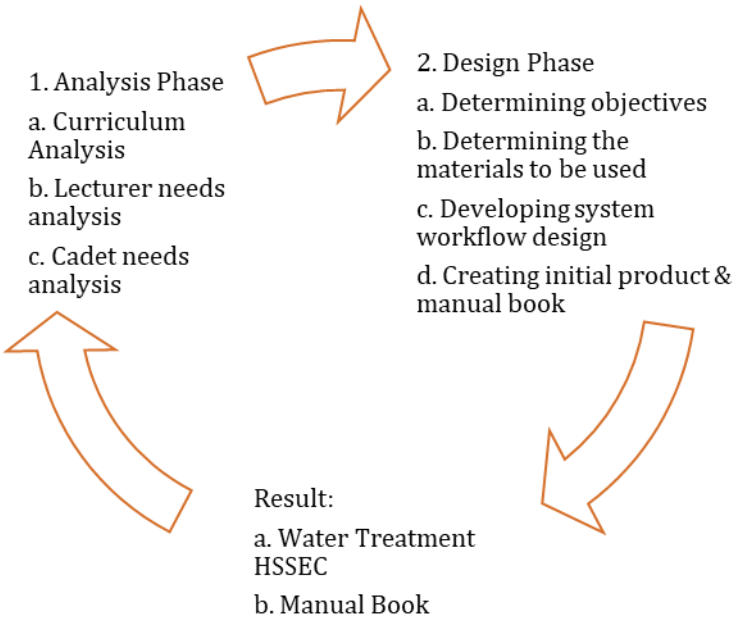


Figure 1. Research Procedures

The research participants consisted of students, lecturers, and experts involved in the development of the Water Treatment HSSEC system at Politeknik Pelayaran Sumatera Barat. Fifth-semester students from the Technology Nautical Study Program participated in the needs analysis stage, whereas second-semester students were involved in the product design stage. Lecturers contributed by providing input regarding instructional needs based on their teaching experience and academic expertise. In addition, subject-matter experts were engaged to validate both the research instruments and the proposed product, thereby ensuring the validity and appropriateness of the development process.

The research instruments consisted of a curriculum analysis observation checklist, a semi-structured interview guide for lecturers, a student needs analysis questionnaire, and photographic

and video documentation collected during the product design stage. All research instruments were validated by experts to ensure their content validity and suitability for data collection. Data collection was conducted in two stages: the preliminary research stage, which involved observations, interviews, and questionnaires to identify product development needs, and the product design stage, which relied on systematic documentation of each step in the Water Treatment HSSEC development process. Data were analyzed using descriptive qualitative and descriptive quantitative approaches according to the characteristics of the collected data. Observation, interview, and documentation data were analyzed descriptively, whereas questionnaire data were analyzed using percentage analysis to determine users' needs for the proposed learning system. The results of these analyses provided the empirical foundation for designing and developing the Water Treatment HSSEC system in accordance with the instructional requirements of the Technology Nautical Study Program at Politeknik Pelayaran Sumatera Barat.

RESULT AND DISCUSSION

1. Analysis Phase

The analysis phase represents the first stage of the Research and Development (R&D) process and aims to identify the needs and problems that form the basis for product development. This phase plays a crucial role because its findings determine the specifications, characteristics, and development direction of the proposed Water Treatment HSSEC system to ensure its suitability for instructional purposes. Through this stage, comprehensive information was obtained regarding the existing learning conditions, current gaps, and users' needs for the proposed system. Furthermore, the analysis ensured that the product was aligned with curriculum requirements, user expectations, and recent developments in maritime technology and industry that support the implementation of Net Zero Emissions. Therefore, the analysis phase served as the primary foundation for designing an effective, practical, and curriculum-oriented learning system for the Technology Nautical Study Program.

Before conducting curriculum observations, lecturer interviews, and student questionnaire surveys, the observation checklist, interview guide, and questionnaire developed by the research team were subjected to expert validation. This procedure was undertaken to ensure that the research instruments possessed adequate content validity, were relevant to the research objectives, and were capable of producing accurate, objective, and reliable data. The validators' comments and recommendations were subsequently used as the basis for revising the instruments, thereby improving their clarity, systematic structure, and overall feasibility for data collection.

Table 1. Validators' Comments for the Research Instruments

No.	Validator	Comments/Suggestions	Authors' Revisions
1	BR, S.E., M.M., M.Mar.E	Please adjust the page margins of the evaluation instrument to the following specifications: left 4 cm, right 3 cm, top 3 cm, and bottom 3 cm.	The page margins were revised according to the recommended specifications: left 4 cm, right 3 cm, top 3 cm, and bottom 3 cm.
2	Dr. (Cand) SY, S.T., M.T., M.Mar.E	1. The numbering format should be arranged vertically rather than horizontally to improve the clarity of the activity sequence. 2. The year of publication should be updated to reflect the current year. 3. Revise the bullet format by using numbers or letters instead of symbols.	1. The numbering format was reorganized vertically to provide a clearer and more systematic sequence of activities. 2. The year of publication was updated to the current year. 3. The bullet format was revised by replacing symbols with numbers or letters in accordance with the prescribed writing guidelines.
3	MFF, S.Tr.Pel., M.Tr.T	Remove the underline from the lecturer's name and check other sections for similar formatting	The underline beneath the lecturer's name was removed, and all other sections with similar

	inconsistencies.	formatting inconsistencies were revised accordingly.

All revisions were implemented in accordance with the validators' recommendations to ensure that the instruments were well organized, systematic, and consistent with accepted academic writing standards. Subsequently, content validity was evaluated using Aiken's V coefficient, with the following interpretation criteria.

Table 2. Aiken's V Criteria

Aiken's V Value	Criteria
$V \geq 0.80$	Very Valid
$0.60 \leq V < 0.80$	Valid
$0.40 \leq V < 0.60$	Fair Valid (need revision)
$V < 0.40$	InValid

The results of the Aiken's V analysis conducted by the three validators for each instrument item are presented in Table 3.

Table 3. Results of Aiken's V Validation

Indicator	Sub Indicator	"V" Observation Sheet	"V" Interview Guidelines	"V" Questionnaire	Categori
Instruction	1	0,89	1	1	Valid
	2	0,78	1	0,89	Valid
	3	1	1	0,78	Valid
	4	1	1	1	Valid
	5	1	1	0,89	Valid
Content / Material	6	1	1	1	Valid
	7	0,89	0,89	1	Valid
	8	0,78	0,78	0,89	Valid
	9	0,78	1	0,89	Valid
	10	1	0,89	0,89	Valid
	11	1	1	1	Valid
Language	12	1	0,89	1	Valid
	13	0,89	0,89	1	Valid
	14	1	1	1	Valid

As presented in Table 3, the observation checklist, interview guide, and questionnaire obtained Aiken's V coefficients ranging from 0.78 to 1.00 for all instrument items. These values indicate that every item satisfied the recommended criteria for content validity, as all coefficients exceeded the minimum threshold for acceptable validity. The validation results further demonstrate that the instructional guidelines, content, and language aspects were considered appropriate by the expert validators, indicating that the instruments were capable of accurately measuring the intended research objectives.

In this study, the analysis phase was conducted systematically through three main components: curriculum analysis, lecturers' needs analysis, and students' needs analysis. These complementary analyses were expected to provide a comprehensive understanding of the requirements for developing the Water Treatment HSSEC system. Consequently, the proposed product was designed to align with the competency standards specified in the IMO Model Course 7.04 *Officer in Charge of an Engineering Watch*, support the instructional needs of the Technology Nautical Study Program, and contribute to preparing future marine engineering officers capable of supporting the implementation of Net Zero Emissions.

a. Curriculum Analysis

The curriculum analysis was conducted on the Technology Nautical Study Program curriculum, which is based on the IMO Model Course 7.04 *Officer in Charge of an Engineering Watch* as the primary framework for the instructional process. The analysis aimed to identify the alignment of learning outcomes, competencies, and instructional content related to water treatment systems and maritime environmental protection principles. Data were collected through an observation of curriculum documents, including

learning outcomes, course structure, course content, and competency standards that students are expected to achieve in accordance with IMO requirements. The findings were used to identify existing needs, gaps, and opportunities for integrating the Water Treatment HSSEC concept into the curriculum to ensure alignment with the expected graduate competencies. Consequently, the curriculum analysis served as the foundation for formulating the specifications of the Water Treatment HSSEC system so that it would be relevant to curriculum requirements, support the operational competencies of future marine engineering officers, and contribute to the implementation of Net Zero Emissions in maritime vocational education. The results of the curriculum analysis for the Technology Nautical Study Program at Politeknik Pelayaran Sumatera Barat are presented in Table 4.

Table 4. Curriculum Analysis Results of Technology Nautical Study Program

No.	Indicator	Expected Condition	Findings/Analysis
1	Alignment of learning outcomes with Water Treatment HSSEC competencies	The curriculum integrates competencies related to the operation of the Water Treatment HSSEC system as part of Marine Engineering competencies in accordance with the IMO Model Course 7.04.	The learning outcomes already cover competencies related to ship machinery operation; however, they do not specifically include competencies associated with the Water Treatment HSSEC system.
2	Water Treatment HSSEC instructional content	Learning materials cover the operating principles, operation, maintenance, and control of the Water Treatment HSSEC system.	Existing instructional materials primarily focus on general ship machinery systems, while Water Treatment HSSEC is not yet comprehensively addressed.
3	Integration of Green Shipping and Net Zero Emissions concepts.	The curriculum integrates Green Shipping, energy efficiency, and Net Zero Emissions concepts into the learning process.	Pollution prevention is included in the curriculum; however, the implementation of Net Zero Emissions through the Water Treatment HSSEC system has not been specifically incorporated into instruction.
4	Availability of instructional media and laboratory facilities	Learning media, simulators, or laboratory facilities for the Water Treatment HSSEC system are available to support students' competency development.	No Water Treatment HSSEC laboratory facilities or simulators are currently available; therefore, learning is still dominated by theoretical instruction and limited demonstrations.
5	Practical learning activities	Students gain hands-on experience in operating and maintaining the Water Treatment HSSEC system.	Existing laboratory activities focus on general ship machinery systems and do not provide practical experience with the Water Treatment HSSEC system.
6	Control and automation systems	Instruction includes sensors, control panels, and automation systems related to the Water Treatment HSSEC system.	Automation concepts are taught; however, they are not specifically linked to the control and monitoring systems of the Water Treatment HSSEC system.
7	Use of water quality measurement	Students are able to operate water quality testing instruments such as	The use of water quality measurement instruments has not yet been incorporated into

	instruments	pH meters, TDS meters, and flow meters during laboratory activities.	laboratory practice; consequently, students' competencies in this area remain limited.
8	Maintenance of the Water Treatment HSSEC system	The curriculum includes maintenance procedures for the Water Treatment HSSEC system based on standard shipboard operating procedures.	Maintenance instruction focuses on general ship machinery and equipment, whereas maintenance of the Water Treatment HSSEC system is not yet included.
9	IMO and MARPOL regulations	Learning activities integrate IMO regulations, MARPOL, Green Shipping, and Sustainable Maritime Operations through practical applications.	IMO and MARPOL regulations have been introduced; however, their implementation through Water Treatment HSSEC-based learning remains limited.
10	Alignment with maritime industry needs	The curriculum equips graduates with competencies in operating Water Treatment HSSEC systems in accordance with the requirements of the modern maritime industry.	The analysis indicates a gap between the competencies required by the maritime industry and the currently available instructional facilities and learning media, highlighting the need to develop the Water Treatment HSSEC system as an innovative learning medium.

Based on the curriculum analysis of the Technology Nautical Study Program, which refers to the IMO Model Course 7.04 *Officer in Charge of an Engineering Watch*, it was found that the curriculum already incorporates fundamental competencies related to ship machinery operation, control systems, equipment maintenance, and environmental protection. Nevertheless, several gaps remain in terms of curriculum content integration, laboratory facilities, and instructional implementation specifically addressing the Water Treatment HSSEC system to support the principles of Green Shipping and Net Zero Emissions. Therefore, the curriculum analysis demonstrates the need to develop the Water Treatment HSSEC system as an innovative learning medium and Teaching Factory capable of supporting students' competency achievement in accordance with IMO standards while addressing the sustainability demands of the contemporary maritime industry.

b. Lecturer Needs Analysis

The lecturer needs analysis was conducted with lecturers of the Technology nautical Study Program who taught courses in accordance with the IMO Model Course 7.04 *Officer in Charge of an Engineering Watch* curriculum in order to obtain information regarding the need for the development of Water Treatment HSSEC in the learning process. Data were collected through semi-structured direct interviews, allowing the lecturers to provide in-depth explanations based on their teaching experience and field-based learning needs. The lecturer needs analysis focused on three main components: *necessity*, to identify the ideal needs related to competencies and instructional media; *lack*, to identify the gap between the current learning conditions and the expected conditions; and *want*, to determine lecturers' expectations regarding the characteristics of the product to be developed. These three components provided a comprehensive description of the learning conditions, the challenges encountered, and the need for instructional media development that is relevant to curriculum demands and developments in technology nautical.

The results of the lecturer needs analysis conducted through interviews with Lecturer 1 (Mr. BR), Lecturer 2 (Mr. SY), and Lecturer 3 (Mr. MFF) are presented in Table 5.

Table 5. Results of Lecturer Needs Analysis in the Technology Nautical Study Program

No.	Analysis Component	Interview Findings

1	*Necessity*	Lecturers stated that Water Treatment HSSEC competencies should be integrated into learning because they are aligned with the requirements of IMO Model Course 7.04, the needs of the shipping industry, and the implementation of Green Shipping and Net Zero Emission initiatives.
2	*Lack*	Lecturers identified limitations in Water Treatment HSSEC teaching materials, practicum media, simulators, and learning modules, resulting in a learning process that has not yet been able to provide optimal practical experience.
3	*Want*	Lecturers expected the development of Water Treatment HSSEC instructional media that resemble actual shipboard conditions, are easy to operate, are equipped with control systems and practicum modules, and are capable of improving students' competencies and supporting sustainable learning.

Table 5 indicates that the development of Water Treatment HSSEC constitutes a relevant need for supporting the learning process in the Technology nautical Study Program. In the *necessity* component, lecturers considered that Water Treatment HSSEC competencies should be integrated into learning in order to align with the requirements of the IMO Model Course 7.04 curriculum, the needs of the shipping industry, and the implementation of Green Shipping and Net Zero Emission initiatives. In the *lack* component, several limitations were identified, including the unavailability of practicum media, simulators, learning modules, and adequate practical experience, indicating that the current learning process has not yet been able to optimally develop students' competencies. In the *want* component, lecturers expected the development of representative Water Treatment HSSEC instructional media that are easy to operate, integrated with theoretical and practical learning, and capable of enhancing students' competencies in accordance with technological developments and the needs of the maritime industry.

c. Student Needs Analysis

The student needs analysis was conducted with 24 students of Batch IX in the Technology nautical Study Program to obtain information regarding the need for the development of Water Treatment HSSEC as an instructional medium. Data were collected using a questionnaire developed based on the needs analysis concept in order to describe students' perceptions of the current learning conditions. The student needs analysis focused on three main components: *necessity*, to identify students' needs related to Water Treatment HSSEC competencies and learning; *lack*, to identify the gap between the existing learning conditions and students' needs; and *want*, to determine students' expectations regarding the characteristics of the instructional media to be developed. These three components provided a comprehensive description of students' needs as the primary users of this research product, thereby enabling the development of Water Treatment HSSEC to be aligned with the characteristics of maritime vocational higher education learning.

The results of the student needs analysis in the Technology nautical Study Program are presented in Table 6.

Table 6. Results of Lecturer Needs Analysis in the Technology Nautical Study Program

No.	Component Analysis	Operational Definition	Mean Score	Categori
1	*Necessity*	Students' perceptions regarding the competencies, knowledge, and skills that should be possessed in accordance with the requirements of the IMO Model Course 7.04 curriculum, shipping industry standards, and Net Zero Emission implementation.	88.23%	Strongly Agree
2	*Lack*	Students' perceptions regarding deficiencies or limitations experienced during the current learning process,	85.83%	Strongly Agree

		including teaching materials, instructional media, practicum facilities, and understanding of Water Treatment concepts.		
3	*Want*	Students' expectations regarding the characteristics, features, functions, and implementation of Water Treatment HSSEC as an instructional medium capable of improving technical competence and environmental awareness.	89.38%	Strongly Agree

Table 6 demonstrates that the results of the student needs analysis indicated a very high level of agreement regarding the development of Water Treatment HSSEC across all needs analysis components. The *necessity* component obtained a mean score of 88.23%, indicating that students recognized the importance of mastering Water Treatment HSSEC competencies in accordance with the requirements of the IMO Model Course 7.04 curriculum, the needs of the shipping industry, and the implementation of Net Zero Emission initiatives. The *lack* component obtained a mean score of 85.83%, indicating that students still perceived limitations in teaching materials, instructional media, practicum facilities, and understanding of the Water Treatment system during the learning process. Meanwhile, the *want* component obtained the highest mean score of 89.38%, indicating that students strongly expected the development of Water Treatment HSSEC as an instructional medium capable of enhancing technical competence, practical experience, and awareness of environmental sustainability in support of Net Zero Emission implementation.

2. Design Phase

a. Water Treatment HSSEC Design

Based on the visualization of the Water Treatment HSSEC installation piping scheme at Poltekpel Sumbar, the mechanical water flow begins sequentially from the infiltration well, where water is drawn by a suction pump and conveyed to the ground tank or settling tank for initial storage and sedimentation. Subsequently, the water flows through a series of treatment units consisting of filtration, purification, and disinfection systems before being stored in a clean-water tank for distribution according to operational requirements. The system was designed by considering the principles of water treatment efficiency, operational safety, ease of maintenance, and conformity with the learning standards of the Technology nautical Study Program and IMO regulations related to maritime environmental protection (Espinosa & Domingo, 2025).

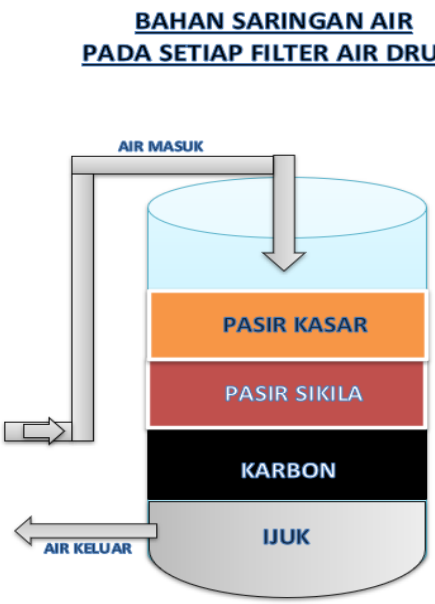


Figure 2. Filter Media in the Drum

Figure 2 illustrates that the filter media in each Water Treatment HSSEC drum are arranged in layers to produce a gradual water filtration process. The filtration layers consist of coarse sand as the initial filter for large particles, silica sand for finer particles, activated carbon for reducing odor, color, and organic content, and palm fiber as both a supporting layer and the final filter before water exits the filtration system. The arrangement of the filter media was designed so that each layer performs a complementary function, thereby enhancing the effectiveness of the water treatment process and improving water quality. With this configuration, Water Treatment HSSEC not only represents the operating principle of filtration systems used in water treatment installations but also serves as an instructional medium that enables students to understand the function of each filtering material in supporting efficient and sustainable water management (Elbertsen et al., 2026).

Furthermore, the water-flow mechanism in each filter drum was designed to illustrate the water circulation process from inlet, filtration, and discharge of the filtered water to the subsequent treatment unit.

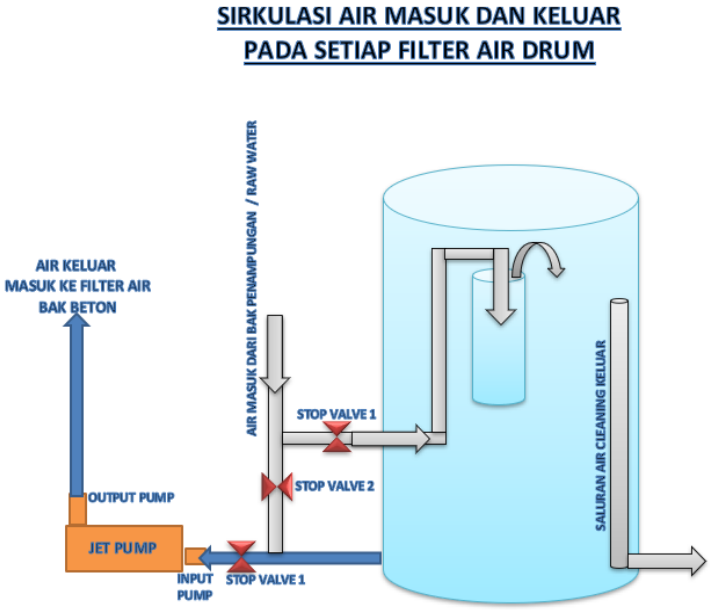


Figure 2. Water Flow Mechanism

Based on Figure 2, the water flow in each filter drum begins with raw water from the storage tank entering through the inlet channel and flowing into the filter drum for the filtration process. The water flow is regulated by stop valves installed at both the inlet and outlet channels, after which the water passes through the filter media before being discharged through the clean-water outlet as the filtration product. The filtered water can subsequently be pumped using a jet pump and conveyed to the concrete water filter tank or to the next treatment unit according to system requirements. This mechanism was designed to ensure that the water circulation process operates in a controlled and directed manner and to enable students to learn the operational stages of the Water Treatment HSSEC system in a practical and systematic way (Abo-khalil, 2024).

The next stage involves an advanced filtration process using a concrete filtration tank to improve water quality before the disinfection stage and distribution as treated water.

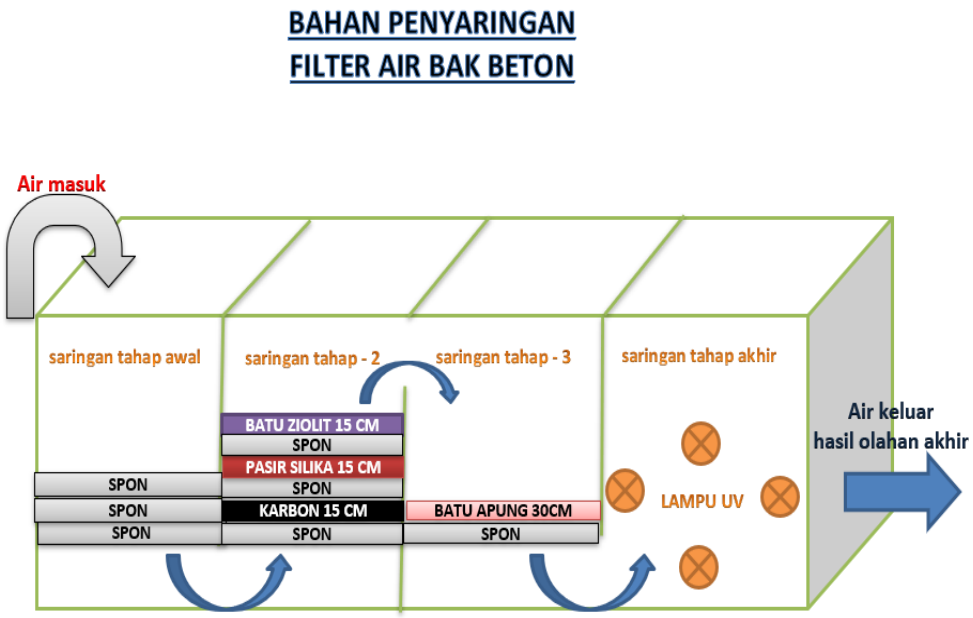


Figure 3. Concrete Filtration Tank

Figure 3 illustrates that the concrete filtration tank was designed using a multistage filtration system to improve water quality through several filtration stages before producing clean water. In the initial stage, the water passes through a sponge layer that functions as a filter for large particles. The water then enters the second stage, which consists of activated carbon, silica sand, and zeolite stones to reduce organic substances, odor, color, and fine particles, before proceeding to the third stage, which uses pumice stone as an additional filtration medium. After the filtration process is completed, the water enters the final stage equipped with an ultraviolet (UV) lamp for disinfection in order to inactivate microorganisms and improve water safety. This sequence of filtration stages demonstrates that Water Treatment HSSEC applies a combination of physical filtration, adsorption, and disinfection as a representation of a comprehensive water treatment system while simultaneously serving as an instructional medium that provides students with a practical understanding of the operating principles of sustainable water treatment installations (Baskoro et al., 2026).

The water movement pathway within the concrete filtration tank is further illustrated in Figure 4.

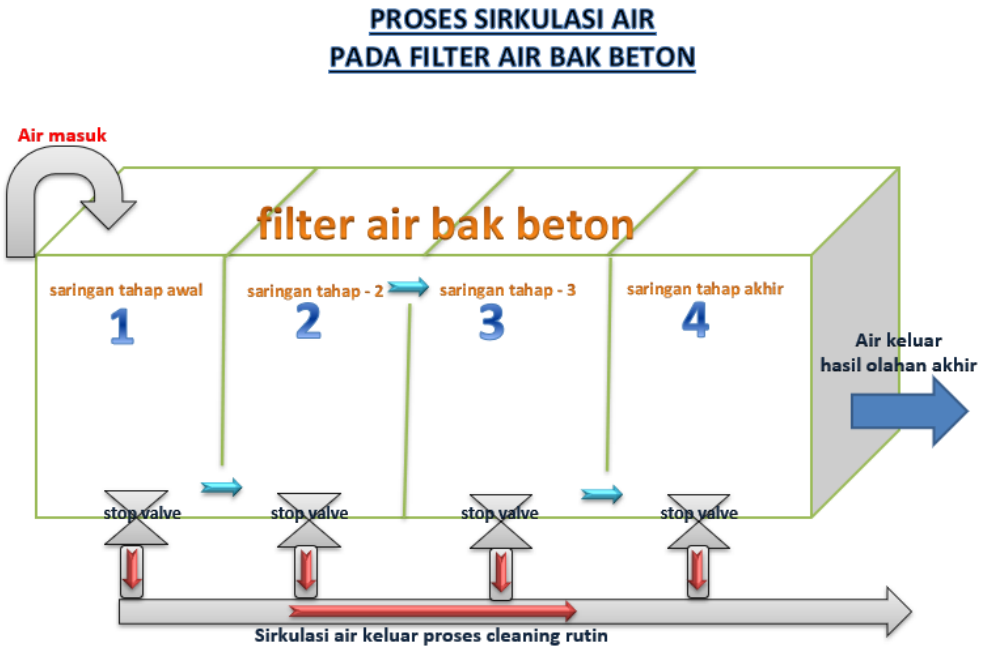


Figure 4. Water Flow Pathway

Figure 4 illustrates that the water circulation process within the concrete filtration tank occurs gradually through four interconnected filtration chambers, thereby producing a systematic water treatment process. Water enters the first filtration chamber and subsequently flows sequentially through the second, third, and final chambers before exiting as treated water that has undergone filtration and disinfection processes. Each chamber is equipped with a stop valve that functions to regulate water flow and facilitate routine cleaning procedures without disrupting the overall water treatment system.

b. Design of the Water Treatment HSSEC Manual Book

The Water Treatment HSSEC module (manual book) was designed as the primary support for the use of the instructional media so that students and lecturers would have a systematic guide for understanding the concepts, operating principles, and operational procedures of the Water Treatment HSSEC installation. The module was developed in accordance with the characteristics of maritime vocational education, which emphasizes a balance between theoretical understanding and practical skills (Abduh et al., 2022). In addition, the content was designed with reference to the competencies specified in the IMO Model Course 7.04 Officer in Charge of an Engineering Watch and integrates the concepts of Green Shipping and Net Zero Emission as part of sustainable learning (Purwantini et al., 2026). The manual book functions not only as a learning resource but also as an operational guide for practicum implementation and maintenance of the Water Treatment HSSEC system.

The structure of the manual book consists of three main chapters arranged sequentially according to stages of competency mastery. Chapter I discusses the philosophical foundation, the Green Campus vision, and the basic theory of water treatment and recycling technologies as a conceptual basis for understanding the importance of sustainable water resource management. Chapter II explains the Water Treatment HSSEC infrastructure architecture, the water cycle pathway, and the specifications and operating mechanisms of each filtration medium so that readers obtain a comprehensive understanding of the system's operating principles. Chapter III presents the Standard Operating Procedures (SOPs) for system operation, preventive and predictive maintenance manuals, and occupational health and safety aspects along with risk mitigation guidelines for the safe and effective use of the instructional media. The final section includes a summary and references to strengthen understanding and provide relevant scientific sources (Hasnur et al., 2026).

The design of the manual book also considered ease of use, systematic presentation of the material, and integration between theory and practice so that it can be used independently or as a companion to practicum activities. Each topic was written in communicative language and supported by illustrations, flow diagrams, component images, and operational procedures that facilitate students' understanding of the Water Treatment HSSEC operating mechanism. Furthermore, each operational and maintenance procedure was arranged sequentially to enable students to apply operating practices in accordance with occupational safety standards and applicable maritime regulations (Uddin & Siska, 2026). The development of this manual book is expected to improve the quality of the learning process, strengthen students' technical competencies, and foster environmental awareness through the implementation of water treatment technology that supports Net Zero Emission (Riyanto, Widiatmaja, et al., 2026).

The development of Water Treatment HSSEC in this study was conducted by adapting the ADDIE model, which was limited to the analysis and design phases. The purpose of this study was to describe the product development process as an instructional medium or Teaching Factory at Politeknik Pelayaran Sumatera Barat (Riyanto, Baskoro, et al., 2026). The analysis phase served as the basis for identifying actual needs that formed the foundation for establishing the product specifications, thereby ensuring that the development process was based not merely on assumptions but on empirical conditions in the field (Rubel et al., 2025). The results of the analysis indicated that the development of Water Treatment HSSEC has strong relevance to the requirements of the IMO Model Course 7.04 Officer in Charge of an Engineering Watch, graduate competency needs, and the policy direction of the maritime industry, which is increasingly oriented toward Green Shipping and Net Zero Emission (Tan et al., 2022). Furthermore, the needs identification results revealed a gap between the expected competencies and the availability of instructional media, practicum facilities, and teaching materials that support learning in water treatment systems.

The design phase represented the process of translating the results of the needs analysis into a product design with both educational and practical functions (Nazarwin et al., 2026). The Water Treatment HSSEC design was developed to resemble water treatment systems used in operational environments, enabling students to learn water circulation pathways, multistage filtration mechanisms, system operation, and maintenance procedures in a more realistic manner (Mofidi et al., 2025). The product design was also complemented by a module or manual book containing the conceptual foundation, system architecture, operating mechanisms, standard operating procedures, periodic maintenance procedures, and occupational health and safety aspects as guidelines for learning implementation (Ejiohuo et al., 2025). The integration of the practical media and the manual book demonstrates that the developed product is not solely oriented toward the provision of equipment but also toward creating a systematic learning experience through the integration of theory and practice.

The development of Water Treatment HSSEC also has strategic value in supporting the implementation of the Net Zero Emission concept through the educational process (Mikropoulos et al., 2025). The Teaching Factory designed in this study provides students with the opportunity to understand that water management, resource-use efficiency, and pollution control are inseparable components of sustainable ship operations (Parsons et al., 2026). Learning that integrates technical aspects with environmental awareness is expected to produce graduates who possess not only operational competencies but also professional awareness regarding the application of sustainability principles in the maritime sector (Wang et al., 2025). Therefore, the development process of Water Treatment HSSEC at the analysis and design stages has produced an instructional media design and its supporting components based on curriculum requirements, user needs, and the demands of the modern shipping industry.

This study has limitations related to the scope of development, which was implemented only up to the analysis and design phases of the ADDIE model. The analysis phase focused on identifying needs through curriculum analysis, lecturer needs analysis, and student needs analysis, while the design phase focused on developing the Water Treatment HSSEC design and the accompanying module (manual book) as supporting

learning tools (Yan et al., 2024). Consequently, the effectiveness, practicality, and feasibility of the product could not yet be measured empirically through implementation in the learning environment. Nevertheless, the product developed in this study has already been realized in the form of a physical product that is ready for use in the learning process (Rehman et al., 2026).

Another limitation is that this study has not yet implemented the three subsequent phases of the ADDIE model, namely development, implementation, and evaluation. In the development phase, the Water Treatment HSSEC design as a tangible product should be complemented by validation from subject-matter experts, media experts, and practitioners to ensure compliance with instructional media feasibility standards (Edegbene et al., 2025). Furthermore, the implementation phase is required to test the use of the product among students of the Technology nautical Study Program on a broader scale, involving all students of the program rather than a single cohort, in order to determine its practicality, ease of use, and influence on the improvement of student competencies (Mendes et al., 2025). Subsequently, the evaluation phase should be conducted through formative and summative evaluations to assess product effectiveness and refine the product based on field implementation results.

In addition, this study has not yet included comprehensive product trials, which are required as a basis for intellectual property protection. Future studies should subject Water Treatment HSSEC to functional testing, operational testing, and user acceptance testing to ensure that the product operates in accordance with the designed specifications (Acheampong et al., 2024). The results of these trials can serve as supporting evidence for design refinement while also demonstrating the novelty and usefulness of the product (Gahrouei et al., 2024). This stage is also one of the important requirements for applying for Intellectual Property Rights protection, particularly patent or simple patent certification, depending on the characteristics of the innovation produced (Rose et al., 2025). Therefore, future research encompassing the development, implementation, and evaluation phases, as well as comprehensive product testing, is expected to produce a Water Treatment HSSEC system that is not only feasible for educational implementation but also possesses innovative value that may qualify for legal protection through patent certification.

The limitations described above were influenced by several constraints encountered during the research implementation. From the time perspective, the study was conducted within a limited period, making it impossible to complete all phases of the ADDIE model up to development, implementation, and evaluation (Tseka et al., 2025). From the financial perspective, the development of Water Treatment HSSEC required a relatively large investment because it involved the procurement of various mechanical and electrical components, control systems, filtration media, water quality measurement instruments, and other supporting facilities requiring substantial funding (Horne & Majola, 2026). Therefore, limitations in time, financial resources, and product complexity became the primary considerations, leading this study to focus on completing the analysis and design phases as the foundation for subsequent development research stages.

CONCLUSION

Based on the findings of this study, the development of Water Treatment HSSEC as an initiative to support the realization of Net Zero Emission at Politeknik Pelayaran Sumatera Barat was conducted using the ADDIE model, which was limited to the analysis and design phases. The results of the curriculum analysis, lecturer needs analysis, and student needs analysis indicated the necessity of developing instructional media that support the achievement of competencies in accordance with the IMO Model Course 7.04 *Officer in Charge of an Engineering Watch* and the implementation of Green Shipping and Net Zero Emission concepts. The design phase produced a Water Treatment HSSEC prototype accompanied by a manual book containing operational procedures, maintenance procedures, and occupational safety guidelines to support practice-based learning. The product design was developed based on users' needs and therefore has the potential to enhance students' technical competencies while fostering awareness of sustainable environmental management.

Theoretically, this study contributes to strengthening the application of the ADDIE model in the development of maritime vocational instructional media that are oriented toward user needs analysis. Practically, the findings may serve as a reference for Politeknik Pelayaran Sumatera Barat in developing instructional media, laboratories, and teaching factories that support Green Shipping and Net Zero Emission initiatives. Future studies are recommended to continue with the development, implementation, and evaluation phases, accompanied by expert validation as well as practicality and effectiveness testing, so that the product can be implemented more broadly and may potentially obtain Intellectual Property Rights protection in the form of a product patent.

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