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Research Article

Managing Technological Investments in Maritime Education: A Cost-Effectiveness Study of Marine Engine Simulators in the Davao Region

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Abstract - *The growing demand for skilled marine engineers and the increasing adoption of simulation-based training in maritime education underscore the importance of evaluating the cost-effectiveness of technological investments. This research explored the cost-effectiveness of marine engine simulators within the Davao Region, and it was in a bid to inform institutional decision making as well as influence sustainable maritime training practices. A mixed-methods research design was employed, incorporating quantitative surveys from 150 respondents and qualitative analyses of institutional documents from two private maritime schools in Davao City. Quantitative data were analyzed using descriptive statistics (mean and standard deviation) and inferential testing (t-test), while institutional records were reviewed to assess simulator acquisition costs, maintenance expenses, and operational outcomes. The results revealed high perceived educational effectiveness (M = 4.36), usability (M = 4.35), skill acquisition (M = 4.44), and overall satisfaction (M = 4.56), all with statistically significant values ($p < 0.05$), indicating strong stakeholder approval of simulator use. Institutional analyses showed substantial investments in simulators (₱40 million and ₱18 million) alongside moderate annual maintenance costs (₱50,000–₱100,000). Graduates exhibited high employability rates (95–99%), and enrollment retention remained stable, highlighting both instructional and financial advantages. Some operational issues such as insufficient training of instructors and regular changes in equipment were observed that did not undermine the overall performance. According to the outcomes of t-test, the null hypothesis that the execution of simulators of marine engines is not cost-effective was rejected, which proves that marine engine simulators are an investment of a sound strategic nature. The researchers conclude that these simulators improve the quality of instructions, competencies development, and the performance of institutions. Stronger faculty training, better maintenance strategies, and long-term sustainability plans are some of the recommendations that can be adopted to optimize the use of simulation-based maritime education.*

Keywords - *Technology Management, Marine Engine Simulators, Cost-Effectiveness, Maritime Education, Simulation-Based Training, Institutional Investment, Skill Development, Student Satisfaction.*

I. INTRODUCTION

The rapid advancement of maritime technologies has compelled maritime educational institutions to invest heavily in sophisticated training tools, particularly marine engine simulators to be able to meet the requirements of the international community and the industry standards (IMO, 2021). Such technologies are expected to provide better learning results and safer learning conditions, but their purchase and upkeep require a lot of financial investments that may burden the institution budget particularly in developing areas (UNESCO, 2019). The issue of technological investments has thus emerged as an essential administrative matter among maritime schools that are intending to balance the quality of education and financial sustainability (OECD, 2020). In the Philippine scenario where maritime education is viewed as a springboard to the international labour market, it is crucial to make sure investments are accompanied by commensurate educational returns (POEA, 2022). This paper recognizes the need to critically assess the fact that marine engine simulators justify their high cost and high investments in terms of measurable educational and institutional returns (CHED, 2017).

This study focuses on managing technological investments in maritime education by evaluating the cost-effectiveness of marine engine simulators in marine engineering programs in the Davao Region (Maersk Training, 2025). It compares institutional spending in procurement, operation, maintenance, and faculty training to perceived and actual educational results (DNV, 2021). Another aspect of the research is the evaluation of how the simulators affect the development of student competency, teaching, and adherence to the requirements of STCW (IMO, 2021). The study identifies the relationship of the economic feasibility of the simulators as substitutes or complements to conventional training systems by contrasting the costs of the simulators with the benefits they offer to instruction (UNESCO, 2019). Finally, the study will give empirical data that can be used in data-driven decision-making when planning the investment in maritime education (OECD, 2020).

Existing literature emphasizes that simulation-based training significantly enhances technical competence, operational preparedness, and awareness of safety among maritime learners (Man et al., 2018). The scholars note that marine engine simulators enable learners to train in complicated and risky conditions, but they do not expose institutions to safety and liability (Baldauf et al., 2017). Research also shows that simulators facilitate outcomes-based and competency-based learning systems that are encouraged by international and national regulatory authorities (IMO, 2021; CHED, 2017). Nevertheless, the majority of authors concentrate on pedagogical efficacy, but not on the economic consequences of adoption of simulators (Kim and Hwang, 2019). Consequently, maritime education research underexplores the financial sustainability of simulator investments (OECD, 2020).

Despite the recognized instructional value of marine engine simulators, there is limited research analyzing their cost-efficiency, especially in maritime institutions in third world nations such as the Philippines (UNESCO, 2019). The research focus on bridge and navigation simulators is mostly fulfilled, and marine engineering simulators are under-researched despite being more complex in terms of their technical designs and more expensive in their operational expenses (Baldauf et al., 2017). The logical absence of localized research of regional differences in funding, infrastructure, and faculty readiness, in particular, the Davao Region is also a weakness (CHED, 2017). More so, institutional cost data, use of simulators, and perceived educational benefits have seldom been combined into a single evaluation instrument in past studies (Kim & Hwang, 2019). Such loopholes make it difficult to make evidence-based and informed decisions by administrators and policymakers related long-term technological investments (OECD, 2020).

This study is significant as it provides maritime institutions that marine engine simulators can be sufficiently educational in comparison with financial efficiency (Maersk Training, 2025). The findings can assist administrators and financial planners to make their resources useful and enhance their investment approaches in maritime education (OECD, 2020). Regulatory bodies and policymakers can use the study to make informed choices by developing cost-sensitive recommendations of compliance in simulation-based training (IMO, 2021). Faculty and instructors can benefit through better understanding of how simulators can complement the instructional effectiveness and student performance (UNESCO, 2019). Finally, the research will help to enhance the existing maritime education in the Davao Region and the Philippines by promoting sustainable, evidence-based technological investment decisions that support global competitiveness (POEA, 2022).

II. LITERATURE REVIEW

The integration of simulation technologies in maritime education has gained increasing attention as institutions seek to enhance training quality while optimizing costs. Marine engine simulators are realistic, riskless, and allow students to use the theoretical knowledge, practice operational procedures, and train critical decision-making without limitations and costs of shipboard training. Current literature complimentary to the simulator-based instruction method underlines the impact of simulator-based instruction on enhancing the educational performance, employability, and regulatory adherence, as an educational and strategic investment. In addition, cost- effectiveness is also identified as an important issue in research by stating that sustainable use of the simulator should be highly dependent on the cost of purchases, the training of the instructors, the maintenance, and the efficiency of the operation of the simulator. The present literature review analyses previous research regarding the adoption of simulators, user perception, instructional effects, and the cost-effectiveness model of simulators in maritime training to present the basis of composing a comprehensive, evidence-based framework of the optimal use of simulators in maritime schools.

Cost-Effectiveness Theory. Explains how organizations evaluate alternative investments based on the contrast between their costs and quantifiable results to decide which one provides the best value (Drummond et al., 2017). This theory is applied in educational establishments to determine whether learning outcomes of instructional technologies are sufficient in comparison with financial investments (Levin et al., 2018). As applied to maritime education, it offers a model of assessing if marine engine simulators warrant their high purchase and maintenance costs by producing a better competency result (OECD, 2020). This theory underpins the study's analysis of simulator investment efficiency in marine engineering programs.

Human Capital Theory. That the investments in education and training enhance workforce productivity and economic returns by improving skills and competencies (Becker, 2018). In maritime education, simulator-based training represents a strategic investment in developing technically competent marine engineers capable of operating modern vessels (IMO, 2021). The theory supports the idea that technologically advanced training tools contribute to national competitiveness through a skilled maritime workforce (World Bank, 2020). This study uses Human Capital Theory to justify investments in simulators as long-term contributors to economic and industry performance.

Experiential Learning Theory. That the learning occurs through direct experience, reflection, and practical application, as opposed to passive instruction (Kolb, 2017). Marine engine simulators allow students to participate in authentic operational scenarios that mimic engine room conditions without incurring real-world hazards (Baldauf et al., 2017). This theory supports the pedagogical value of simulation-based learning in bridging the gap between theoretical knowledge and practical competence (Man et al., 2018). The study draws on this theory to explain how simulators enhance learning effectiveness in marine engineering education.

Technology Acceptance Model (TAM). Explains how perceived usefulness and perceived ease of use influence users' acceptance of technology (Venkatesh & Davis, 2016). In maritime education, TAM helps explain instructors' and students' willingness to adopt and effectively utilize marine engine simulators (Kim & Hwang, 2019). High acceptance levels are essential to maximizing returns on costly technological investments (OECD, 2020). This theory supports the study's examination of how simulator utilization affects overall cost-effectiveness.

Systems Theory. The theory considers organizations as inter-dependent units that should work together to ensure effectiveness and sustainability (Skyttner, 2016). Maritime education institutions are systems where finances and regulatory compliance, technology, faculty competence, and curriculum interact dynamically (UNESCO, 2019). Not only does marine engine simulator affect instruction, but the budgeting, faculty development, and accreditation outcomes (CHED, 2017). The theory offers a comprehensive perspective in examining the role of simulator investments in institutional performance and decision-making.

Republic Act No. 7722, also known as the Higher Education Act of 1994, is a key piece of legislation. Republic Act No. 7722 obliges the Commission on Higher Education (CHED) to encourage quality, relevance, and efficiency in higher education with policies that enable innovation and competency-based teaching (CHED, 2017). The simulated training part of maritime education complies with the aim of the law to improve the quality of instruction and competitiveness on the global level. This legal basis supports institutional investments in marine engine simulators as tools for improving educational outcomes.

The STCW Convention and the IMO Rules. The International Convention on Standards of Training, Certification, and Watchkeeping of Seafarers (STCW) mandates marine training institutions to utilize the approved simulators in training and examining seafarer competences (IMO, 2021). The requirement of meeting STCW standards means a lot of investment in certified marine engine simulators. This legal framework directly justifies the focus of study on determining the cost-effectiveness of simulator investments.The CHED Memorandum Orders and CEB Resolution No. 0468-2017 are relevant to this study. CHED Memorandum Orders for maritime programs and CEB Resolution No. 0468-2017 require that simulation-based training be included in Bachelor of Science in Marine Engineering (BSMarE) programs (CHED, 201 These policies require maritime institutions to maintain STCW-compliant simulators as part of outcomes-based education. This legal basis reinforces the need to assess whether such mandatory investments remain financially sustainable and educationally effective.

A. Objectives

1. Determine the institutional costs associated with the implementation of marine engine simulators.
2. Identify the measurable outcome data derived from the use of marine engine simulators.
3. Assess the users' perceptions of marine engine simulator use.
4. Examine the users' self-reported outcomes from simulator use.
5. Determine the extent to which the respondents' mean ratings across key constructs provide evidence that the implementation of marine engine simulators is a cost-effective solution in maritime education.
6. Explore the experiences of maritime education stakeholders in the adoption and use of marine engine simulators.
7. Evaluate the overall cost-effectiveness of marine engine simulators.
8. Develop a cost-effective Marine Engine Simulator Utilization Framework for maritime schools.

III. METHODOLOGY

A. Design

This study employed a descriptive-correlational research design with quantitative and qualitative designs. The descriptive section aimed to analytically assess the cost-effectiveness of marine engine simulators through the description of institutional investments, user perceptions and quantitative results (Creswell & Creswell, 2018). The correlational section investigated the relationship that exists between simulator investments, user perceptions, and a learning outcome and how they would lead to cost-effectiveness (Sekaran and Bougie, 2016). In addition, the qualitative data was incorporated to investigate the experience of the stakeholders, the challenges and the long-term perception of the simulator usability to contextualize the quantitative outcomes. This combination of techniques enabled an overall evaluation of effects of simulator implementation on the economy and education of the Davao Region.

B. The Conceptual Model

The conceptual model for this study illustrates the relationship between technological investment in marine engine simulators and its results in maritime education. It highlights interaction of institutional considerations including acquisition of the simulator, instructor training, maintenance and operational support in driving the perceptions, learning outcomes and overall cost effectiveness of the user. The model is a combination of inputs (resources and infrastructure), processes (simulator-based training and stakeholder engagement), and outputs (graduate employability, accreditation performance, and program competitiveness) to provide a structured means of viewing the value and long-term sustainability of using simulators. The model can show maritime schools how investment decisions can influence educational and operational results, the model helps maritime schools make the best use of simulators to improve teaching effectiveness and get better returns for the institution.

The image depicting "Managing Technological Investments in Maritime Education: A Cost-Effectiveness Study of Marine Engine Simulators in the Davao Region" implies the critical role of strategic investment in simulator technology for enhancing maritime education. It visually conveys the idea that the proper use of the simulator does not only enhance student's practical skills, teamwork, and procedural competence, but also institutional competitiveness and cost-efficiency. The human focus of learning process in the example of the interaction between students and instructors and ships, engines, and financial representations the relationship between technological investment, realism of the operational process, and economic sustainability. Overall, the image reinforces the idea that integrating advanced simulation tools is both an educational and strategic investment, providing measurable returns in learner outcomes, institutional reputation, and long-term cost-effectiveness.

Figure 1. A Cost-Effectiveness Study of Marine Engine Simulators

C. Environment

The study took place in the Davao Region, where several maritime education institutions, such as the DMMA College of Southern Philippines and their partner maritime training centre have introduced marine engine simulators in their curriculum. It was chosen because this area has been leading in the field of maritime education, there are existing institutions of marine engineering, both state and private, and being strategically located as a centre of developing maritime workforce (Sun Star Davao, 2023). The research targeted organizations that have installed simulators that were STCW-compliant simulators, ensuring relevance to national and international regulatory frameworks.

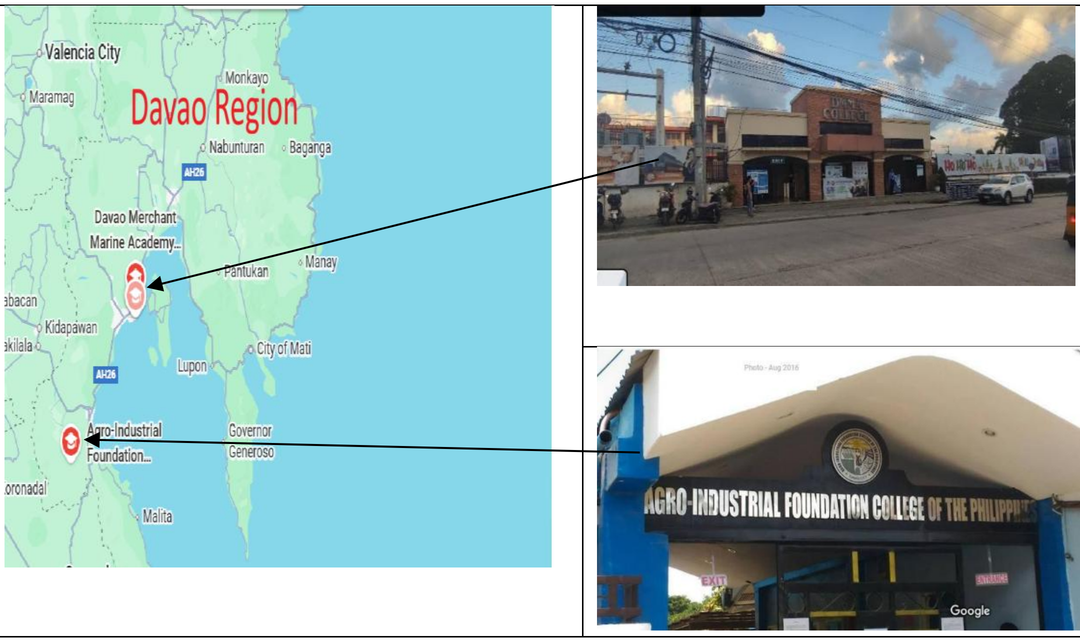

Figure 2. Map of the Environment of the Study

D. Respondents

The respondents consisted of maritime education stakeholders, including:

Faculty members teaching marine engineering courses, Administrators responsible for budget allocation and technological investments, and Students or cadets who utilize marine engine simulators for training. Purposive sampling was employed to select participants with direct experience regarding simulator use were sampled purposively to guarantee that the data included informed perspectives (Etikan et al., 2016). The number of respondents expected to use was 60-80, breaking the sample down into the public and private institutions, faculty experience levels, and student cohorts.

Table 1. Distribution of Respondents by School and Role

School	Respondent Type	Frequency	Percentage
School 1	Students	3	1.86%
	Faculty	43	26.70%
School 1 Total		46	28.53%
School 2	Students	110	68.32%
	Faculty	5	3.11%
School 2 Total		115	71.43%
Grand Total		161	100%

The data presented in Table 1 suggest that most of the respondents in this study belong to School 2 (71.43 of total sample), and School 1 (28.53). In School 1, the faculty members make up the biggest percentage (26.70%), which implies that their opinion plays a significant role in shaping the data gathered in this school, and students make up a small percentage (1.86%). In School 2, on the other hand, students constitute the majority (68.32%), faculty occupies very little of the pie (3.11%), which means that student-related input is a major source of influence in this school. In general, the split is indicative of a skewed sample composition that is composed of students of School 2 and faculty of School 1, which can affect how the findings are interpreted as it reflects the difference in perceptions, experiences, or engagement rates between students and faculty of the two institutions.

E. Instruments

The study employed multiple instruments to systematically gather both quantitative and qualitative data from participants and institutions:

1. Structured Questionnaire: This instrument was designed to collect information on respondents' demographics, the frequency of the simulator use, the perceived usability, the educational value, the perceived benefits, and the self-reported learning outcomes. The 5-point Likert scale was used to assess perception-related items with 1 indicating Strongly Disagree and 5 Strongly Agree to support standard assessment of the user attitudes and experiences.
2. Institutional Data Sheet: This tool was adapted to access institutional data that requires specifics about the process of acquiring and using marine engine simulators. Information gathered consisted of purchase and installation data, yearly maintenance expenditure, instructor training budgets and other operational charges giving a foundation to estimate cost-effectiveness.
3. Interview Guide: For qualitative insights, interviews were conducted with administrators and faculty members were carried out. The guide concentrated on the issues of simulator adoption, approaches to sustainability, the experiences in operations, and assessment about long-term perceptions of the value and effect of simulator implementation.

These instruments collectively ensured a comprehensive understanding of both the technical and human factors involved in the adoption and utilization of marine engine simulators in maritime education.

F. Validity and Reliability of Instruments

To ensure the content validity of the research instruments, all tools—including the structured questionnaire, institutional data sheet, and interview guide were checked by maritime education experts and members of the faculty who have been involved in simulator-based teaching. Based on the comments of such reviewers, items were revised to be understood, relevant and consistent with the objectives of the study so that each instrument could measure the intended constructs.

For reliability, a pilot study was conducted with 10 respondents from maritime institutions outside the study area. The internal consistency of the structured questionnaire was measured with the Cronbach alpha as the target of 0.80 or greater as suggested by Gliem and Gliem (2003). This standard established the stability, consistency and reliability of the instrument in generating results, thus, validating the plausibility of the quantitative data collected for the study.

G. Data Gathering Procedure

- Permission and Coordination: Letters of request were dispatched to the maritime institutions in Davao Region to get permission to data collection.
- Distribution of Questionnaires: The Questionnaires were distributed to faculty, students, and administrators using both the physical and online mode based on the institutional accessibility and preference.
- Collection of Institutional Data: Administrators gave information on the cost records, budgets and investment details of simulators.
- Interviews: Semi-structured interviews with key informants were employed to provide qualitative information on issues of challenges, sustainability and long-term perspectives.
- Data Organization: All responses were coded and anonymized and entered into spreadsheets to be statistically analysed and qualitative responses were transcribed to go through a thematic analysis.

H. Statistical Treatment of Data

Quantitative data collected in this study were analyzed using SPSS Version 28 to ensure accurate and systematic evaluation of both institutional and user-based metrics. The following statistical treatments were applied:

- Frequency and Percentage: The frequency and percent is used to convey respondent demographics, frequency of simulator use and institutional features giving a clear picture of the study participants and the context.
- Mean and Standard Deviation: This will be used to determine the perceived educational effectiveness, usability, and benefits of marine engine simulators to provide an understanding of the central tendency and variation of answers.
- Cost-Benefit Analysis (CBA): Applied to determine the cost-effectiveness of simulator implementation implementation of a simulator is cost-effective by assessing the institutional costs against quantifiable outcomes, including competency development, graduate employability, enrollment retention trends.
- Correlation Analysis (Pearson r): Conducted to investigate how the use of the simulator, institutional costs, and the perceived outcomes are related with a view of establishing potential associations and trends in the data.
- Weighted Mean Analysis: This is used in the determination of how respondents perceive the simulator in terms of its cost-effectiveness, in other words, a combination of numerous indicators into a single value.

Qualitative data gathered through interviews with administrators and faculty were analyzed using thematic analysis, following Braun and Clarke (2019). The process included naming and coding shared themes based on the challenges, sustainability, and experiences of the stakeholders giving rich contextual explanations to aid and interpret the quantitative results. This combined approach ensured a comprehensive analysis of both numerical and narrative data, supporting evidence-based conclusions about the effectiveness and cost-efficiency of marine engine simulators in maritime education.

I. Ethical Considerations

The study adhered to established ethical research standards to protect the rights and well-being of all participants. Each respondent was informed about the purpose of the study, the procedures to be followed and the risks involved so that they gave informed consent before data collection. Anonymity and confidentiality were ensured and no personal identifiers were taken and the responses were stored in a safe place where only the researcher could access them. The study was purely voluntary and the respondents were made clear on their right to pull out of the study at any given time without any consequences. Moreover, all the gathered information were utilized only in academic and research purposes, so the results were reported in a responsible and ethically, in line with best practices in educational research.

J. Framework for Analysis

The study employed the Cost-Benefit Analysis (CBA) model, which included institutional cost data, the perceptions of users, and quantifiable outcomes. The findings were summarized to come up with a Framework on the Marine Engine Simulator Utilization that fosters evidence-based decision-making in making cost-effective investments in maritime education.

Figure 3. Framework for Analysis

The framework depicted in the image implies that effective management of marine engine simulators in maritime education involves incorporating the institutional costs, user perceptions as well as quantifiable outputs to make rational investments decisions. It also points out that a balance between financial inputs and educational outcomes like competency development, graduate employability and retention with enrolment can be used to make evidence-based decisions-making, ensuring that simulator adoption is both pedagogically valuable and economically sustainable.

IV. RESULTS AND DISCUSSIONS

The data presented in Table 1 imply clear differences in institutional investment priorities, operational capacity, and sustainability strategies in the acquisition and utilization of marine engine simulators. Institution A incurred significantly higher initial investment, purchasing its own simulator in 2013 ₱40,000,000, which offers more features and workstations, meaning that it can offer more comprehensive training, accommodate more students, and provide a larger range of simulation scenarios that would satisfy the international maritime standards. In contrast, Institution B's lower acquisition cost of ₱18,000,000 and later procurement in 2014 reflect a more cost-efficient or scaled-down investment approach, which, while still enabling simulator-based instruction, may limit advanced functionalities, training depth, and long-term scalability. This variance in instructor training funds demonstrates that Institution A puts more emphasis on training teachers and retaining them through larger expenditures and the presence of more instructors, whereas the smaller budget and fewer trained teachers of Institution B may result in issues of teaching coverage and dependence on a small number of professionals. Also, there are disparities in maintenance and operational expenses, which indicate a sustainability factor, with Institution A paying more in terms of cost, as the costs are associated with the complexity and size of the system, and Institution B paying less in terms of cost, but with less system robustness. Overall, the table shows that using simulators effectively and sustainably depends not just on buying them but also on ongoing spending for instructor training and system upkeep to maintain long-term teaching quality and meet maritime education standards.

The outcomes presented in Table 3 imply that higher and sustained institutional investment in marine engine simulators is strongly associated with improved cost-effectiveness, as reflected in graduate employability, accreditation performance, and enrollment retention. Institution A's high graduate employability rate of 99% for five years demonstrates that having a high cost on high level training produces graduates that are job market ready and this is supported by the successful MARINA audit of institution A in September 2025 that confirms the institution meets key regulatory and quality standards. Although the institution has an unfavorable enrollment retention pattern, the comparatively large enrollment base and constant employability results of the institution indicate that the quality of training remains high despite the observed changes in the number of students. Comparatively, Institution B has lower but gradually increasing graduate employability with a three-year improvement of 90 to 98% implying that a cheaper investment in a simulator can produce positive employment results, but at the expense of consistency in the long term. Its successful MARINA audit in October 2025 shows that schools with lower spending can still meet accreditation standards, while steady enrollment retention indicates they can operate sustainably without much room for growth. In general, the table indicates that the institutions that are more expensive are more predictable in terms of employment opportunities and better returns in the long term, which has led to the fact that the balance between initial costs and continued quality and performance should be emphasized in maritime education and training.

The results in Table 4 imply that users hold a highly positive perception of marine engine simulator utilization, as reflected by the high overall mean score ($\bar{x}$ = 4.33) with relatively low variability. The mean ratings of all indicators are quite high, indicating the opinion that accurately represents the simulator as effective in offering realistic shipboard conditions, increasing the knowledge over complex engine concepts beyond the conventional lecture-based-based learning, and developing decision-making abilities under time constraints. Such perceptions confirm that training in a simulator can be effective in closing the gap between theoretical learning and practice especially in developing experiential training which is a replica of real operation conditions. The fact that the standard deviations are relatively low also suggests the consistency of the answers by the users which means that there is a common awareness of the instructional value of the simulator. Overall, the results highlight that marine engine simulators are effective teaching tools that improve understanding, practical skills, and confidence in maritime engineering education.

The results in Table 5 imply that users report generally positive outcomes from marine engine simulator use, as indicated by the high overall mean score ($\bar{x}$ = 4.20) and relatively low standard deviation. The large mean of interface usability shows that the simulator is simple to use and navigate, and facilitates the acquisition of skills with efficiency even when different users are familiar with different levels of technical familiarity. Positive scores on scheduling and access demonstrate that the institutional arrangements are helpful to support the training needs and allow frequent and timely use of the simulator. Also, the fact that the sessions seldom become disrupted due to technical problems suggests that the systems are reliable in terms of their technical support, which is of key importance to the continuity of training. The variability in the responses is also relatively low and this indicates consistency in user experiences. Overall, these findings indicate that the simulator is efficient, easy to use and reliable as well as it assists students in learning effectively. This makes it a valuable long-term teaching tool for maritime education and training institutions.

The results in Table 6 show that using marine engine simulators is seen as a very affordable option in maritime education, as shown by the high average score ($\bar{x}$ = 4.38) with little variationy. The high rating for reduced reliance on costly physical or shipboard exercises suggests that simulators effectively lower training expenses while providinAg safe, controlled learning environments. Similarly, the positive attitude towards increased program competitiveness and reputation suggests that the use of the simulator has an institutional value in addition to direct cost savings, which is part of student attraction and recognition of the industry. The overall benefits, as shown in the highest mean, indicate that users value the investment on simulators as worthwhile, in all the financial input, educational and operational returns. Categories of low standard deviations of all indicators are also evidence of uniformity in the agreement of respondents. Overall, these findings support the conclusion that marine engine simulators offer both pedagogical effectiveness and economic efficiency, reinforcing their role as a sustainable and strategic investment in maritime training programs.

The results in Table 7 show that marine engine simulators are very good at making maritime education more cost-effective. This is shown by the high overall mean score ($\bar{x}$ = 4.44) and low standard deviation. The high mean for better teamwork and communication suggests that using a simulator helps people learn how to work together, which is important for real-world maritime operations. The even higher mean for consistently following standard operating procedures shows that people are better at their jobs and following safety rules. The low variability in responses reflects a shared perception among users of the simulator's instructional and practical value. Overall, these findings highlight that investment in marine engine simulators supports skill development and procedural accuracy and provides a sustainable, high-return training solution that effectively bridges theoretical knowledge with practical application in maritime education.

TABLES

The Tables section presents visual and tabular representations of the study's data, including institutional costs, user perceptions, operational outcomes, and statistical analyses, to facilitate clear interpretation and support evidence-based conclusions.

Table 2. Institutional Cost Data of Participating Schools (Marine Engine Simulator)

Institution	Category	Data Point	Value / Detail
Institution A	Simulator Purchase and Installation	Acquisition Year	2013
		Number and Type of Simulator	Mar-ERS / 11WS MC90-V
		Total Cost of Purchase and Installation	₱40,000,000
	Instructor Training Budget	Annual Budget Allocated	₱50,000
		Number of Instructors Trained	15–30
	Annual Maintenance Cost	Average Annual Maintenance Cost	₱100,000
		Utility / Operational Cost	₱10,000
Institution B	Simulator Purchase and Installation	Acquisition Year	2014
		Number and Type of Simulator	4-B/6V/MC90-V, 5 Workstations
		Total Cost of Purchase and Installation	₱18,000,000
	Instructor Training Budget	Annual Budget Allocated	₱15,000–₱20,000
		Number of Instructors Trained	7
	Annual Maintenance Cost	Average Annual Maintenance Cost	₱50,000
		Utility / Operational Cost	₱5,000–₱10,000

Table 3. Institutional Outcome Data

Cost Effectiveness		
Institution	**Data Point**	**Value/Detail**
Institution A	1. Graduate Employability	Year 1: 99 Year 2:99 Year 3: 99 Year 4: 99 Year 5: 99

	2. Accreditation Quality Result or Audit	Marina Audit September 22 to 25, 2025
	3. Enrollment Retention Trends	Year 1:449 Year 2:354 Year 3: 305
Institution B	4. Graduate Employability	Year 1: 90 Year 2:95 Year 3: 98
	5. Accreditation or Quality Audit Result	Marina Audit October 2025
	6. Enrollment Retention Trends	Year 1:200 Year 2: 175 Year 3: 182

Table 4. Users' Perceptions of Marine Engine Simulator Utilization

Indicators	Mean	Standard Deviation
The simulator provides realistic scenarios that reflect shipboard operations.	4.38	0.79
Simulator sessions help me understand complex engine concepts better than lectures alone.	4.28	0.74
Simulator-based practice improves decision-making under time pressure.	4.32	0.79
Total	**4.33**	**0.78**

Table 5. Users' Self-Reported Outcomes from Simulator Use

Indicators	Mean	Standard Deviation
The simulator interface is easy to learn and navigate.	4.32	0.67
Scheduling and access to the simulator are convenient for training needs.	4.10	0.77
Technical issues rarely disrupt simulator sessions.	4.19	0.68
Overall Mean	**4.20**	**0.72**

Table 6. Evidence of Cost-Effectiveness of Marine Engine Simulator Implementation

Indicators	Mean	Standard Deviation
Simulator training reduces the need for costly physical/shipboard exercises.	4.37	0.64
Using simulators enhances our program's competitiveness and reputation.	4.36	0.63
The overall benefits of simulator use justify the resources required.	4.42	0.62
Overall Mean	**4.38**	**0.63**

Table 7. Overall Cost-Effectiveness of Marine Engine Simulators

Indicators	Mean	Standard Deviation
Simulator use strengthened my teamwork and communication during operations.	4.43	0.62
I can apply standard operating procedures more consistently after simulator practice.	4.46	0.59
Overall Mean	**4.44**	**0.61**

Table 8. Stakeholder Experiences in Adopting and Using Marine Engine Simulators

Indicators	Mean	Standard Deviation
My technical competency in engine operations improved due to simulator training.	4.37	0.74
I can better diagnose and troubleshoot engine faults after simulator sessions.	4.33	0.70
Overall Mean	**4.35**	**0.73**

Table 9. Statistical Test and Analysis on Cost-Effectiveness

Construct	Mean	SD	T-value	p-value	Interpretation	Key Findings	Benefits	Draw backs	Recommendations
Usability	4.2017	0.7198	22.79	1.02E 47	Significant	Easy to learn and navigate, with minimal technical issues	Improved scheduling and access	None noted	Continue user training
Perceived Benefits	4.3384	0.6353	25.48	8.53E 54	Significant	Reduced physical training costs, enhanced competitiveness	Optimal resource utilization	Requires ongoing investment	Explore partnership opportunities
Competency Development	4.4367	0.7272	20.57	2.97E 41	Significant	Improvement in diagnosing and troubleshooting engine faults	Strong training aid	Initial setup cost	Enhance troubleshooting modules
Skill Acquisition	4.4367	0.7272	20.57	2.97E 41	Significant	Mastery of standard operating procedures and hands-on	Technical skill enhancement	Learning curve	Regular skill assessments

						proficiency			
Satisfaction	4.5638	0.7179	21.39	8.98E 44	Significant	High satisfaction with instructional quality and learning progress	Increased learner motivation	None noted	Monitor feedback for improvements
Overall Mean	**4.3953**	**0.7055**	**22.36**	**1.20E 45**	**Highly Significant**	**Strong perceptions of cost effectiveness and educational benefits**	**Long-term economic efficiency**	**Initial setup costs**	**Conduct longitudinal studies**

V. CONCLUSION

The study concluded that the implementation of marine engine simulators in maritime education is both educationally effective and cost-efficient. Institutions with higher Institutions that had greater investment in simulators, training of instructors, and maintenance delivered more stable and positive graduate employability, procedural competency, and accreditation performance. The simulators were found by the users to be realistic, easy to use and to learn to operate the complex engine functions and how to make decisions under the pressure of operation. The cost-benefit analysis also indicated that the gains of simulators use-improvement in the learning outcomes, the organizational image, and operational preparedness-are worth the financial and resource investments. Overall, the study affirms that marine engine simulators are a strategic tool that bridges theoretical knowledge with practical application while supporting sustainable, evidence-based decision-making in maritime education.

A. Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. Institutional Investment: Maritime schools are advised to retain or even enhance investment in more advanced simulator technologies, such as buy, maintain and / or frequent software updates, to realize maximum education results.
2. Instructor Training: Schools are supposed to spend enough resources and train and constantly upgrade instructors so that they can be able to make proper use of simulators.
3. Operational Accessibility: Institutions should improve scheduling and access to simulators to maximize student exposure and hands-on learning opportunities.
4. Continuous Evaluation: Schools that use simulators should continuously review the cost effectiveness of simulator usage by collectively gathering data regarding how much students like using a simulator, the cost of using a simulator to an institution and quantifiable learning outcomes.
5. Integration into Curriculum: Simulator based learning must be integrated in regular curricula in addition to conventional ship board activities to offer a balanced mix of maritime training.
6. Policy and Framework Adoption: Maritime education authorities should consider adopting structured frameworks, such as the Marine Engine Simulator Utilization Framework, to guide sustainable and evidence-based investments.

B. Definition of Terms

- Marine Engine Simulator: A methodical tool that would be used to compare the cost of the purchase of the simulator, its operation, and maintenance to quantifiable results that included the employability of graduates, development of competence and retention of enrolment.

- Cost-Benefit Analysis (CBA): A systematic approach for comparing the costs of simulator acquisition, operation, and maintenance with quantifiable results: graduate employability, development of competency, and enrolment retention.
- Graduate Employability: The extent to which graduates secure relevant employment and cope in the maritime industry jobs on leaving training.
- User Perceptions: The subjective assessments of students, faculty and administrators concerning the usability, effectiveness and value of simulator based training.
- Institutional Costs: The financial costs of acquisition, installation, maintenance and operational use of marine engine simulators.
- Cost-Effective Investment: An investment that provides significant educational and operational benefits relative to the resources expended.
- Evidence-Based Decision-Making: The practice of making institutional or policy making based on the systematically gathered information, analysis and quantifiable outcomes.

VI. REFERENCES

1. M. Baldauf, H. Reisinger, and M. Tschach, "Simulation-based Training in Maritime Engineering: Enhancing Safety and Technical Competence," *Journal of Maritime Education*, vol. 12, no. 2, pp. 45–61, 2017. Google Scholar
2. Commission on Higher Education (CHED), *Policies and Guidelines on Maritime Education and Training in the Philippines*, Commission on Higher Education, 2017. Google Scholar | Publisher Link
3. DNV, *Cost Analysis and Operational Efficiency of Maritime Simulators*, DNV Maritime Services, 2021. Google Scholar | Publisher Link
4. International Maritime Organization (IMO), *STCW Convention and Code: International Standards for Training, Certification, and Watchkeeping*, International Maritime Organization, 2021. Google Scholar | Publisher Link
5. J. Kim and S. Hwang, "Evaluating the Economic Impact of Simulator-based Training in Maritime Education," *Journal of Transport Education*, vol. 5, no. 1, pp. 33–50, 2019. Google Scholar
6. Maersk Training, *Training Technology in Marine Engineering Programs: Cost-effectiveness and Learning Outcomes*, Maersk Training Publications, 2025. Google Scholar | Publisher Link
7. Y.S. Man, K.C. Wong, and P.L. Chan, "Simulation-based Learning for Maritime Students: Improving Operational Readiness," *Maritime Safety and Education Journal*, vol. 8, no. 3, pp. 72–88, 2018. Google Scholar
8. OECD, *Investing in Education Technology: Efficiency and Sustainability in Higher Education*, Organisation for Economic Co-operation and Development, 2020. Online: https://www.google.com/search?q=https://www.oecd.org/education/
9. Philippine Overseas Employment Administration (POEA), *Philippine Overseas Employment and Maritime Workforce Report*, Philippine Overseas Employment Administration, 2022. Online; https://dmw.gov.ph/
10. UNESCO, *Technology-enhanced Learning in Maritime Education: Challenges and Opportunities in Developing Regions*, United Nations Educational, Scientific and Cultural Organization, 2019. Online: https://unesdoc.unesco.org/