Simulator Training in the Marine Engineering Technology Curriculum

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Abstract

Marine Engineering Technology program curriculum is focused on the application of the technical sciences to solve problems associated with marine equipment, systems, and vehicles. As defined by ABET, the MET program must train graduates to be proficient in the operation, maintenance, analysis, and management of marine power plants and associated marine auxiliary equipment and systems. By the addition of simulator training into the MET course curriculum, the instructor can close the gap between theory and application. The instructor can utilize the simulators to create an interactive environment where students can learn to work effectively as a team to diagnose systems and machinery faults representative of those encountered in the real-world operation of steam and diesel propulsion power plants. There are two different environments in which the transfer of learning occurs: full mission and part task trainers. The Full mission simulators consist of engine control room, emergency diesel generator room, instructor operating room, and engine room. The part task trainers are individual computer workstations, running the same plant model as the full mission simulator, to assess individual knowledge. The topics that are included in the training are casualty procedures and critical thinking, problem solving under stressful environments that are commonly encountered in real-world, startup and shutdown procedures, exhaust treatment equipment including waste heat recovery, and advanced engine technologies applied to the reduction of harmful emissions.

1. Introduction

The Marine Engineering Technology (MET) program focuses on applying engineering principles to marine equipment, systems, and vehicles. The practical skills of a marine engineer should include operation, maintenance and repair, analysis, and management of the marine auxiliary equipment and systems by ensuring safety. In today’s world, due to the greater complexity of larger ships, in addition to the ship’s machinery operations, marine engineers are required to be trained in decision making to address risk and uncertainty with resources and technology. Despite the advancement of technology in the ships, the safety and the efficient operation rest entirely in the hands of marine engineers. So the quality of marine engineering education and training is critical to raise the skill levels of marine engineers by knowledge transfer of real-world operations.

Simulators may be a powerful substantial tool that can imitate or replicate real-world scenarios to complement on the interface in the effect of practical and theoretical requirements. In a simulator training the student learns by performing the activities in a context that is like the real-world.

Simulator training provides an opportunity for a student to build a mental model of a real-world scenario and test the solution in safety without fear of injury and damage to the equipment. Simulator programs can be developed or upgraded using software to suit any training environment. This allows students to go through exercises with variable operating conditions of any engine room machinery or system that could be completely inadmissible in the realism. Although, simulators may not be a true replacement for sea time experience, the exercises can prepare students with necessary rapidity and vigilance that are expected in ship's operation.

This paper is focused on the simulator training that is included in the MET at California State University Maritime Academy (CSUM).

2. Simulator Models and Specifications

Cal Maritime operates four engine room simulators. These simulators are described by "model," which is the type of propulsion system and equipment, and "mission," which describes the training environment. The mission types are

- Full mission – These include multiple operating/control stations, multiple rooms, sound, and heat. Multiple students operate the simulator as a group.
- Part task trainer (PTT)– These are single computer-based terminals that allow a user to access all controls of an individual simulator.

A. Steam Simulator –
Ship Model Specification

- 180,000 dead weight ton tanker
- Main engine – Approximately 32,000HP cross compounded HP and LP turbine connected to double reduction combining gearbox turning one propeller shaft
- Boilers – Two dual burner boilers rated at 150,000-200,000 lbs/hr (adjustable); superheated steam at 875# and 900F and de-superheated steam at 875#.
- Generators – Two 900kW steam turbines and one 900kW diesel generator, one 300kW emergency generator.
- Switchboards – One ship's service switchboard and one emergency switchboard
- Major modeled system – Fuel oil, feed water, condensate, auxiliary steam, lube oil, sea water cooling

Training Environment -
Full Mission

- Engine room (Figure *3*)
  - Hardware to interact with plant; valves, actuators, indicator lights, simulated fire and smoke
  - Student computer station (Figure 1)
- Control room
  - Hardware to interact with plant; gages, buttons, indicator lights, sound

- Emergency diesel generator room
    - Hardware to interact with plant; gages, buttons, indicator lights
- Instructor station
    - Instructor computer
    - CCTV monitors

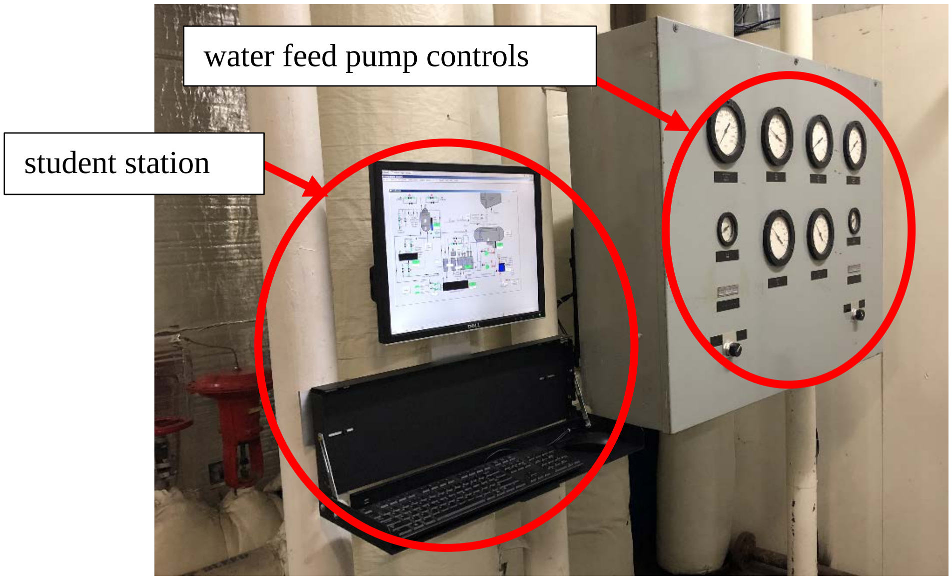

Figure 1. Steam simulator student station

Part Task

- Part task stations (PTT)
    - Six stations with single 24” screens
- Instructor computer

B. Diesel Simulator I –
Ship Model Specification

- Very large crude carrier
- Main engine – MAN B&W 5L90ME. 6-cylinder slow speed diesel engine
- Generators – Three 1200kW diesel generators, one 1200kW shaft generator, one 400kW emergency generator

Training Environment

- Virtual walk around room
    - One 60" vertical touchscreen, two 60" vertical screens
    - One 24" touchscreen for navigation and equipment control
    -

- Emergency diesel generator room
    - Virtual switchboard on touchscreens
    - Touchscreen for navigation around plant

- Control room (Figure *2*)
- Instructor station

Figure 2. Diesel simulator I control room

C. Diesel Simulator II–
Ship Model Specification

- K-Sim MC90-V. 188,000 dead weight ton tanker.
- Main engine – MAN B&W 5L90MC. Approximately 23,000HP 5-cylinder slow speed diesel engine
- Generators – Two 900kW diesel generators, one 1000kW shaft generator, one 900kW steam turbine generator, one 250kW emergency generator

Training Environment –
Full Mission

- Control room
    - Main engine control console
    - Main switchboard and generator controls
- Engine Room (There are multiple options in this engine room)
    - "Big view"
    - Local operating stations

- Emergency diesel generator controls and switchboard
- Instructor station (combined with part task instructor station)

Part Task Trainer

- Part task station
  - Nine stations with dual 24" screens
- Instructor Station (combined with full mission instructor station)

D. Diesel Simulator III

Ship Model Specification

- Same model as diesel simulator II

Training Environment – III

- Instructor station (in the same room)
- Part task stations
  - Two stations with dual 24" screens
  - Two stations with dual 60" screens

Figure 3. Diesel simulator II "big view" and engine room

Figure 4. Diesel simulator III

3. Simulation Training

MET students at Cal Maritime are required to take four simulator classes ranging from introduction to operating the entire plant with a team of people. All the classes are taught with class size ranging from 6-9 people.

The first exposure to simulation in the curriculum is on the Training Ship Golden Bear (TSGB), which is operated by CSUM. This vessel is a 500' long training vessel that sails around the globe with 300-315 students onboard, training in the operation of the vessel. The simulator onboard TSGB is utilized during the annual 2-month training cruise.

During the training cruise, students will spend approximately 9 hours in simulator training. These students have just completed their freshman year, and for many it's a first-time sailing experience in their life. While on this cruise, the students will divide their time between classes (that includes simulator training), watch standing (operations), and day working (conducting maintenance). Because this is an operating ship, the students are operating under the direct supervision of licensed maritime officers, and the room for error is minimal. Unfortunately, this learning pedagogy does not train students to deal with every conceivable abnormal situation. The simulator becomes the venue for the freshman to experiment with the unpredictability of operating equipment that they may witness in the engine room, in a safe environment.

Figure 3. Steam full mission engine room

The students can be trained with variety of situations by tailoring creative simulator exercises. For example, an assignment that is given to the students during a simulation evolution is to establish power on a vessel that is dead ship (all power sources secured). The students are required to use the ship's emergency generator to start raising power to systems on the ship to eventually get one of the ship's main diesel generators operational. The resultant skills and knowledge gained by such exercises are better applicable to situations that are not explicitly practiced.

One of the earlier interactions the student has with the simulator is with the emergency diesel generator switchboard, Figure 4 showing a simulated switchboard and Figure *5* showing a typical emergency switchboard aboard a vessel. Both the simulated switchboard and the actual switchboard have circuit breakers and gauges.

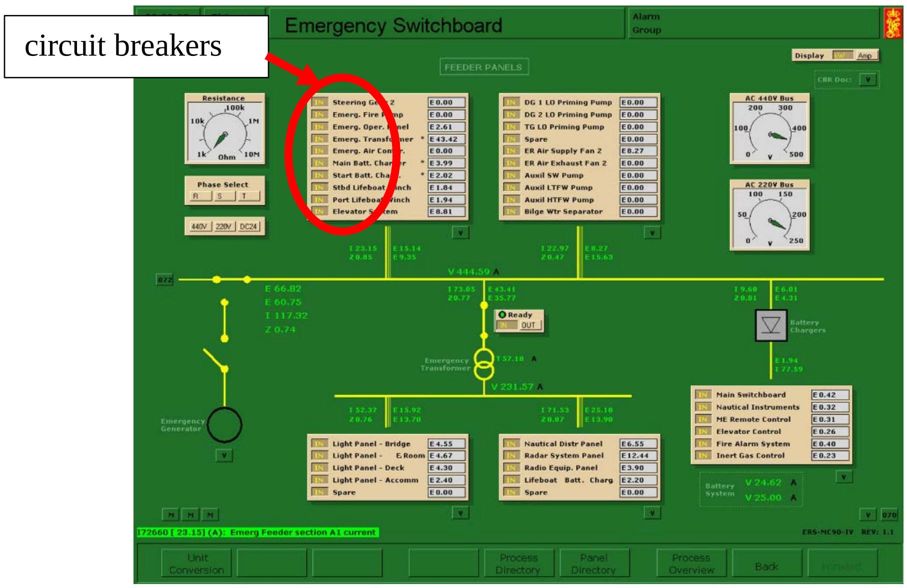

Figure 4. Simulated emergency switchboard

Figure 5. Ship's emergency switchboard

Systems involved in addition to the emergency power system are compressed air, sea water cooling, freshwater cooling, fuel oil, and lube oil. All these systems are present on the training ship and the students are expected to operate parts of these systems while they are on watch. All these systems are typical on the ships that the students will be operating after graduation. Figure 6 depicts an actual cooling system control page from the control system of a ship while Figure *7* depicts the simulator's version of the similar system. In this instance, the manufacturer of the simulator and the actual control system are the same, and they have similar design language to aid the students in transitioning from the simulated environment to a shipboard environment post-graduation.

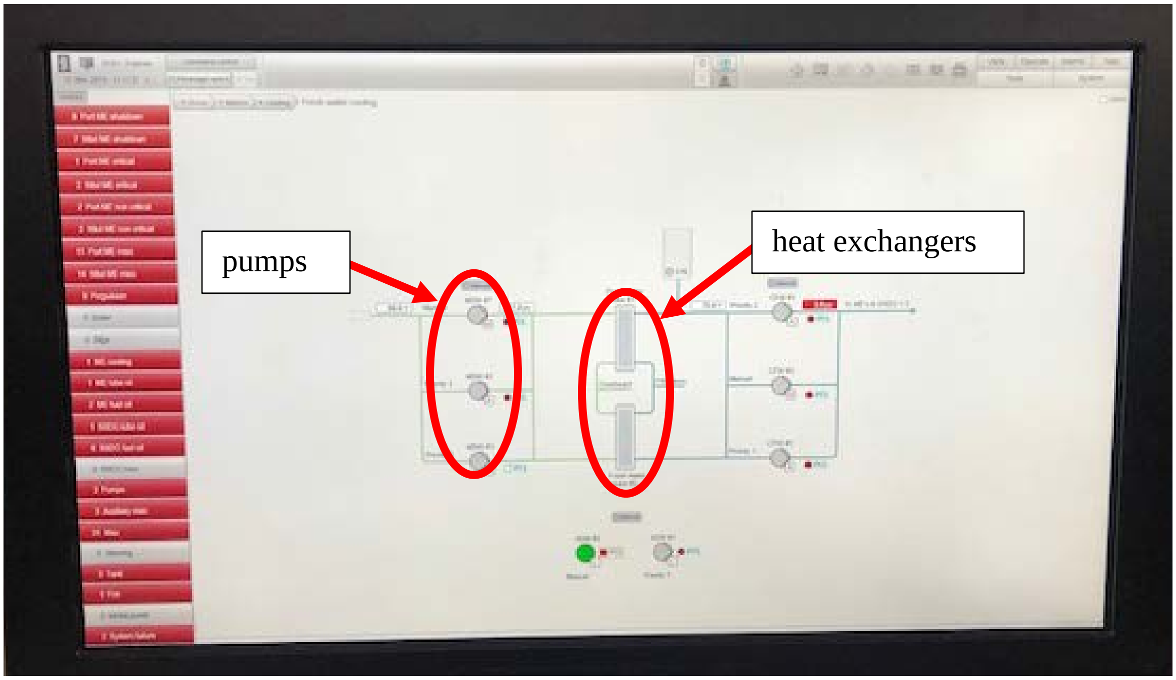

Figure 6. Typical engine room cooling pump control

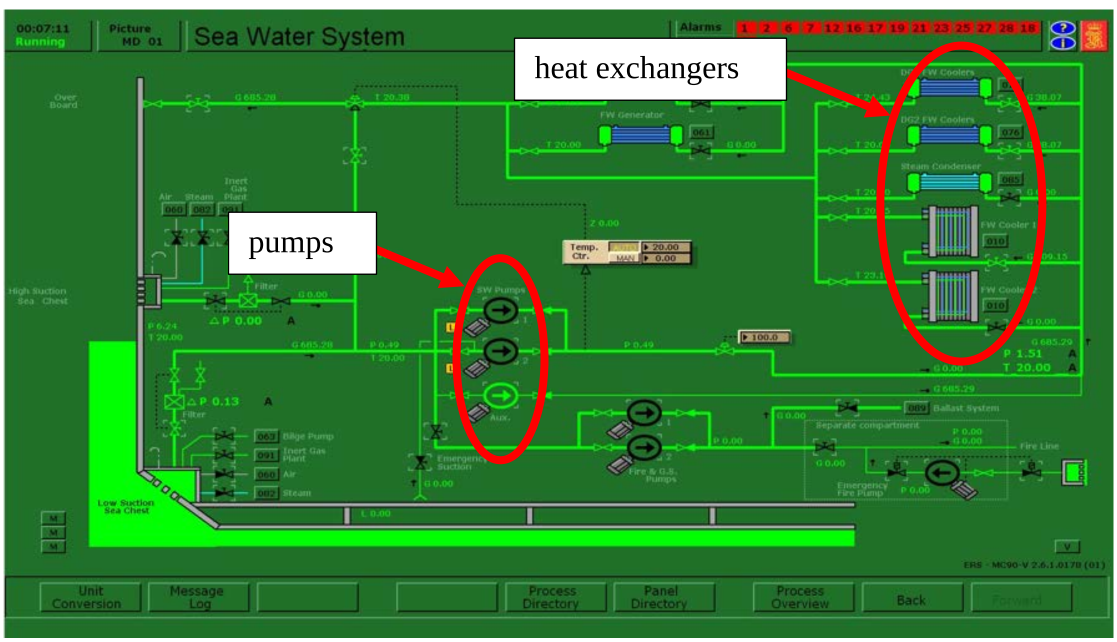

Figure 7. Simulator cooling pump control

The next experience the students have with simulation is an introductory course on the operation of a shipboard propulsion steam plant. This occurs sophomore year after the students have returned from the training cruise. This class has fixed training evolutions:

- Evolution 1 – Raise electrical power aboard the simulated vessel
- Evolution 2 – Light a boiler using diesel fuel
- Evolution 3 – Transfer the boiler from diesel fuel to heavy fuel oil
- Evolution 4 – Start a turbine-driven feed pump
- Evolution 5 – Raise vacuum in the main condenser; secure a boiler.

The evolutions are presented to the student by the instructor; the evolution is practiced and then then is tested. These are very task-specific evolutions that are designed to meet the requirements of licensing. The Marine Engineering Technology students are required to obtain a 3rd Assistant Engineering License for graduation. Upon graduation, they will be licensed to operate the engineering plants in diesel engine, steam engine, and gas turbine-propelled vessels. CSUMA does not have a steam propelled vessel and is fully reliant on the simulator to train the students in proper operation. Figure 8 shows cadets in the control room of the steam simulator operating the plant. Figure 9 shows a control station of an active steam ship.

Figure 8. Steam plant simulator control room

Figure 9. Typical steam plant control console

The post-requisite for the initial steam plant operation course is called "Watch Team Management." This course takes a radically different approach from the previous course and is directly aimed at preparing students for a career post-graduation. The goal of the class is to operate a vessel in real time throughout the semester while working as a group. At the beginning of the semester, each class section is assigned a vessel. The vessel's initial condition is inherited from the previous semester's class ending point. Each subsequent week builds on the previous week. All events that take place, including those errors initiated by the student crew itself, will carry through from week to week. In addition to student-initiated errors, equipment and system anomalies can be initiated by the instructor.

In addition to the experiential education in which the learning simulates real-time environment, simulators can also be used to develop leadership competencies that are critical in maritime industry. The students are expected to operate in a leadership structure like what is found on a commercial vessel. Each student will spend two weeks in the assigned position and are expected to operate as each role by the end of the semester. The roles are:

- Chief engineer – Manager of the evolution and the 1st assistant engineer and all paperwork.
- 1st assistant engineer – In charge of operating the plant and supervising all subordinates.
- 2nd assistant engineer – Generally in charge of operating boilers.
- 3rd assistant Engineer – Generally in charge of operating supporting systems in the plant.
- Oiler – Assist as assigned
- QMED (qualified member of the engineering department) – Assist as assigned

All attempts are made to ensure a realistic experience in this class. A major goal of this class in preparation of a career aboard a vessel is to test the student/student group in a safe environment with no risk of equipment damage. During an instructor or student-initiated engineering casualty, multiple stressors become active. Multiple loud audible alarms activate; their "annoyance" levels increase depending on severity of the casualty. There are also visible strobe alarm lights for different levels of alarm. If the casualty becomes severe enough that the power generation systems trip offline, the lights will go out in the simulator, leaving the students to rely on flashlights until they restore power. The simulator can generate nuisance alarms. We can easily generate alarm fatigue, illustrating the effects and the results of ignoring alarms, which usually results in more simulated equipment damage.

Other devices are employed in the simulation environment that aren't necessarily part of the electronic simulation of the ship. Students are required to work in a harsh environment; the engine room is heated to 110-120˚ F, which is common to a commercial ship. They are also required to use communication tools that will be available to them in a real environment such as radios and sound powered phones. Students are required to fill out paperwork that will be required of them in industry.

Safety is a paramount concern onboard vessel. Vessel operators are required to have a safety management system (SMS) that governs procedures for normal and abnormal operations, defines levels of authority, environmental policies, etc. There are established procedures for personnel to work under an SMS.

One of the major preventative procedures required by an SMS is filling out a job safety analysis (JSA) or a job hazard analysis. This document requires defining the job, who is involved, what the risks are, what safety equipment is required, environmental impacts, and the process to complete the job. Every job onboard a vessel requires this level of analysis to prevent injury, loss of life, or damage to equipment. This initially may appear to be cumbersome to the student, but it is a required practice in maritime industry. The earlier we can acclimate a student to this procedure, the more likely it will be completed properly in the industry post-graduation. JSAs are required in the simulated environment. An example task that requires a JSA is to remove the stack covers off of a boiler that has been secured. There is no smokestack for the simulator, nor covers, but the student must estimate what the risks are, and the safety equipment required to go onto the top of a small platform 120' above the waterline to remove a heavy piece of steel.

Additional paperwork required of the student (and required by a SMS and the USCG) are "near miss" forms and United States Coast Guard (USCG) CG-2692. The "near miss" forms are required when an accident occurs but nothing is damaged or no one is hurt. The CG-2692 is required when an accident occurs and there is damage, injury, or loss of life, or loss of control of the ship. In the simulated environment, the most common occurrences requiring the CG-2692 are loss of propulsion plant and improper boiler lighting procedures.

The final simulation experience that students have in the curriculum is in the diesel simulator II. The structure of this class is very similar to the first class in the steam simulator. There are six evolutions that are conducted to prepare the student to operate a ship with a slow speed diesel propulsion system:

- Evolution 1 – Raise power from dead ship condition.
- Evolution 2 – Start ship's boiler on distillate fuel and start to warm equipment, fuel oil, lube oil, and jacket water. Start ship's refrigeration system. Verify operation of ship's sewage system.
- Evolution 3 – Prepare main engine fuel oil system to operate on heavy fuel oil. Line up and start second SSDG on heavy fuel oil. Secure first SSDG. Place fuel oil purifiers in operation and begin to transfer fuel.
- Evolution 4 – Perform steering gear and EOT tests. Prepare main engine for departure. Ship's service turbine generator to be placed online. Power management system online in automatic. Backup systems in automatic.
- Evolution 5 – Prepare main engine for departure. Maintain systems while the bridge maneuvers. Prepare the shaft generator for operation. Begin making fresh water with a distiller. Begin treating bilge water for discharge. Secure boiler when waste heat recovery boiler is providing adequate steam. Provision power management system for underway conditions.
- Evolution 6 – Transition equipment to distillate fuel and place selective catalytic reduction system into operation to reduce emissions. Place boiler online. Pump ballast out of tanks. Start the inert-gas generation system.

These evolutions are what a student would see while preparing a slow speed diesel propelled tanker for getting underway from a dock and transiting to an ocean voyage. This simulation is critical to prepare the students for typical marine propulsion systems. The students in the course of their studies will spend 120 days sailing aboard the TSGB, gaining familiarity with the diesel propulsion system; however, the engines and drivetrain on the ship are not typical of industry. The main differentiator is that the engines of the TSGB are medium-speed type with clutches. This means that the engines typically operate at speeds of 150-500 RPM and can be de-clutched from the propeller. The industry has trended towards slow speed propulsion engines with a direct connection to the propeller. These engines operate in the range of 40-100 RPM and are constructed significantly differently than medium speed engines. The diesel simulator II model is a slow speed model.

4. Assessment of Students

Simulators can also be used to sought student learning experience so the assessment knowledge can be a driving influence on adapting teaching pedagogical practices. In classes where there is specific procedural training in the operation of the ship such as the first steam simulator class or the diesel simulator class the student must be assessed on their individual comprehension of material as well as their ability to perform the actions as a group. For each of the evolutions presented in class, there is a written test. Then the student must demonstrate the evolution in the part task trainer, and then the group will demonstrate the evolution in the full mission simulator. They are evaluated on the completeness and accuracy while in the simulator.

Figure 9. Diesel simulator II control console

Figure 10. Diesel ship control console

Watch Team Management is a rubric-based evaluation system. There are no fixed evolutions that the teams are conducting, so there is an evaluation given during each session spent in the simulator. There are both group and individual evaluations. The group is evaluated on systems and engineering principles, situational awareness, and crew resource management. The individual is evaluated on preparedness. Debriefs are conducted after every evolution to discuss the students' performance.

In addition to the performance in the simulator, the students are graded on the completeness of paperwork and the condition of the plant. The paperwork being evaluated are JSAs, "near miss", CG-2692, the logbooks that are required to be filled out during every evolution, tracking of fuel consumption, etc. The students are also given a ship's budget for the semester. Whenever an error is made in simulation that results in equipment damage, a penalty is assessed to the ship's budget. If significant simulated equipment damage occurs over a semester, a grade can be severely impacted. Additionally, a piece of equipment may be irreparable due to insufficient funds, and that piece of equipment is no longer available for use in the simulation.

5. Conclusions

In this paper, the authors have presented how and why simulator-based training is implemented in the Marine Engineering Technology curriculum at California State University Maritime Academy. The simulator training addresses the issues of training effectiveness, situational preparedness in a real-time environment by ensuring safety. In simulator training, students take risks as if they were confronted with real-life situations without having to suffer the consequences of failure. Simulators save time and money, reduce risks, and work well in teaching decision-making skills that are critical for a marine engineer. The simulator training provides flexibility in the learning environments with more opportunities to make complicated abstractive concepts easier to understand by practicing creative exercises.

Biographical Information

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