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Project-Based Coursework in a Naval Architecture Curriculum

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Abstract

Studies have shown the benefits of incorporating design projects into engineering courses. These projects allow the students to directly apply the course topics in "hands-on" applications, while also providing the students opportunities to develop group project skills. In the small field of naval architecture little has been written of these projects. This paper presents the details of five courses using this approach in the Naval Architecture and Ocean Engineering Department (NAOE) at the United States Naval Academy (USNA). The first course is the major's introductory course for sophomores where after seven weeks each student submits the specification, calculations, lines plan and construction drawings for a towing tank model. These plans are then turned over to another student to build and test. The second course is a junior-level structures course focusing on ship structures. The students design a full midship section. The final three courses are at the senior-level and include an elective in marine fabrication methods and two capstone design courses. In the fabrication course small student groups design, build, perform QA/QC tests and proof-test a series of components in metal, reinforced concrete and composites. This course focuses on the benefits of design-for-manufacturability and instills this approach through the actual time it takes the students to design, build and document their group projects. The capstone courses include a fall semester class that has each student prepare the preliminary design of a specific small vessel. During the spring semester student groups prepare preliminary designs of a vessel of their choice. It is the department's hope that these project-based courses provide the students with a better understanding of the complete ship design process. Positive feedback on student evaluation forms indicate the students enjoy the approach and alumni comments indicate they feel the approach is worthwhile.

Introduction

The USNA was established in 1845 and is the premier institution staffing the officer corps of the Navy and Marine Corps. Its mission is "to develop midshipmen morally, mentally and physically and to imbue them with the highest ideals of duty, honor and loyalty in order to provide graduates who are dedicated to a career of naval service and have potential for future development in mind and character to assume the highest responsibilities of command, citizenship and government". The Academy provides the 4100 midshipmen the opportunity to pursue studies in engineering, science or humanities. Due to a large focus in math and science in the required courses, all students receive a Bachelors of Science Degree. The ABET-accredited

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engineering disciplines include aerospace, electrical, mechanical, ocean, and systems engineering and naval architecture.

The Naval Architecture Program at the USNA includes four civilian professors with doctorates and eight military instructors with at least masters degrees. The major's program teaches nine required courses and three to seven electives per year. In addition, each semester approximately 15 sections of 18-22 students are taught in EN200 – Naval Engineering 1 (Introduction to Naval Architecture); a course required for all non-engineering majors. In USNA terms, the course follows a (3-2-4) format, which translates as three hours of lecture and two hours of lab each week for four credits. All freshmen share a similar curriculum comprising chemistry, calculus, history, government, English, leadership, seamanship and physical education. Majors are declared near the end of freshman year. Over the last decade the Naval Architecture Program has graduated between 17 and 26 students each year. Currently the program has 30 freshmen, 31 sophomores, 21 juniors and 24 seniors. This makes the program one of the largest naval architecture programs in the country[1]. The department also offers an Ocean Engineering major with approximately 200 students.

The general program curriculum follows the classic "design spiral" practiced by countless naval architects over the years. Figure 1 shows the design spiral and figure 2 shows the USNA course sequence. In 2003 the Principles of Ocean Systems Engineering course was renamed Principles of Naval Architecture.

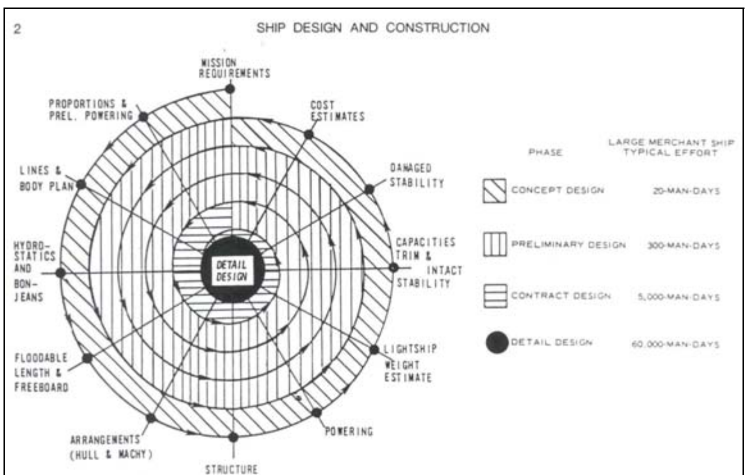


Figure 1: Naval architecture design spiral[2]

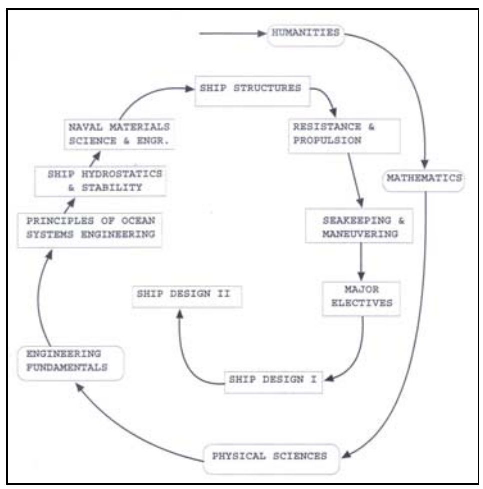


Figure 2: Course Sequence

EN246 – Principles of Naval Architecture

After a fall semester of physics, calculus, statics, ethics, navigation and PE, the sophomores take their first course in the major. The general course concept is to give the students an overview of the major discipline topics in a (2-2-3) format. Table 1 shows the topics covered. It is clear that depth is sacrificed at the expense of breadth!

Spreadsheets	Buoyancy	Stability	Resistance
Sketching	Drafting	Specifications	Construction
Statistics	Probability	Power plants	Wind and Wave Forces
Reliability	Engineering Ethics		

Table 1: Topics In Introductory Naval Architecture Course

The first six weeks teach the students the foundations of naval architecture and set them up to perform a simple design project constituting 25% of their course grade. The project concept is that each student will design a small balsa ship model (12-24 inches long) to carry a cargo down the towing tank using a gravity tow system. The student prepares the calculations, design specifications and submits the lines plan, midship construction section drawing, building patterns and a description of the design philosophy. The design package is then turned over to a classmate in a random drawing. The classmate then builds the vessel and runs the test. The team of builder and designer that have the lowest time (indicating the least hydrodynamic resistance) receive gift certificates to a local restaurant. Each year the amount of balsa and the cargo are varied to avoid type-forming. The 2003 competition included one sheet of balsa (3”x42”x1/8”) and ten 35mm film canisters half filled with sand as cargo. The professor graded the design package and an industry panel of three graded the construction. The grade split was 60/40 for design/construction. In addition to reinforcing the course topics the students also experience the challenging relationship between designer and builder. Builders are required to document all “change orders” and to update the drawings to “as-built”.

Great enthusiasm is generated during the project and the final trials take on a festive atmosphere. Figure 3 shows a typical run from the 2002 competition and figure 4 shows one class holding up the boats they built. Student evaluations reflected the enthusiasm generated, with virtually universal praise for the project.

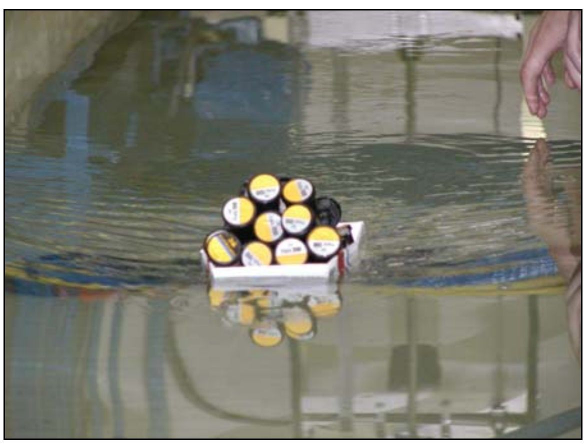


Figure 3: Balsa model in tank

Figure 4: EN246 students with models

EN358 – Ship Structures

This (3-2-4) spring semester course follows a general strength of materials course taught to all engineers and introduces the student to designing ships to withstand longitudinal and transverse loads. Early topics include primary and secondary loads, section modulus calculation, plate equations, buckling and shipbuilding materials. The third quarter of the course (and 20% of the course grade) is based on the design of a complete midship construction section of a medium-sized commercial vessel. The students are provided the vessel's principal dimensions, lines plan and service-life operating conditions (such as "year round North Atlantic") and are required to determine the loads and the structural capacity required. Figure 5 shows an example of the finished product's complexity. The students use spreadsheets to analyze the stresses and are graded on structural accuracy, weight efficiency, construction cost and drawing neatness.

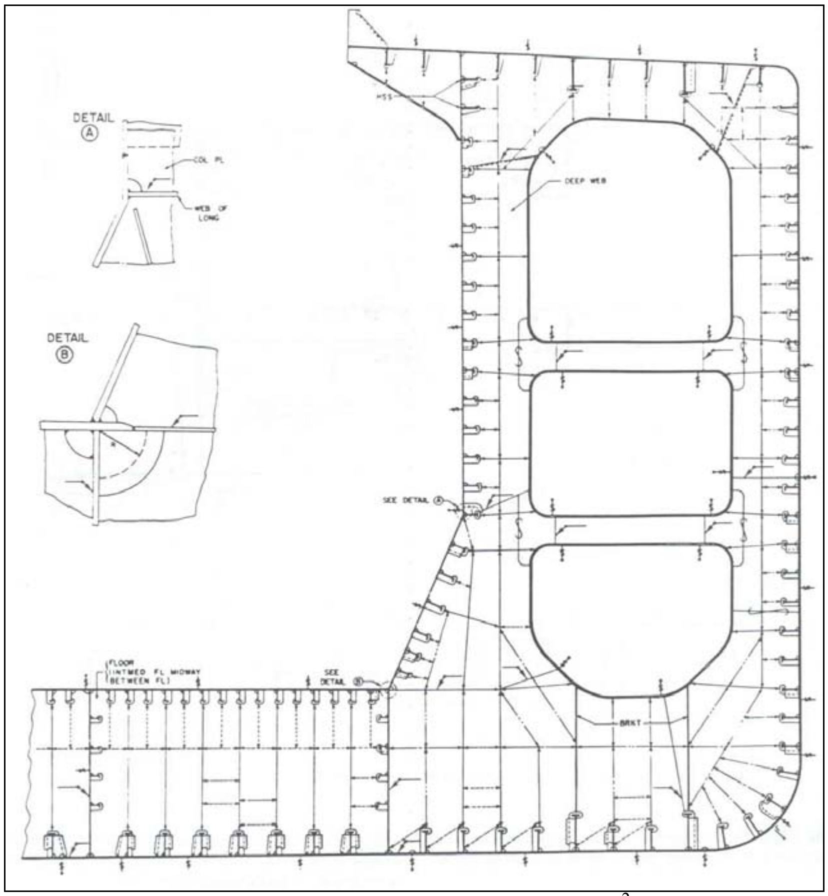


Figure 5: Midship Construction Section[2]

EN445 – Marine Fabrication Methods

A typical ship or offshore engineering project follows the phases of design, analysis, fabrication, installation, maintenance, and decommissioning, and most undergraduate engineering courses focus on design and analysis. This course introduces the students to the fabrication, installation and maintenance phases, and was a direct result of feedback from officers in the fleet. Comments included observations that although the junior engineers were capable of adequate analysis, their designs often could not be efficiently built or maintained[3].

This senior-level elective (2-2-3) presents the basic fabrication methods used to build offshore structures and structural components aboard ships. Every other week the lab focus is on a different hands-on fabrication method, such as welding, riveting, bolting, machining or laminating. Lectures provide analytical background providing design methods for the specific fabrication method. The intervening labs are for quality control non-destructive and destructive testing of the components built by the students. The course covers fabrication methods for metals, reinforced concrete and composites, generally following a path of increasing analytical and fabrication complexity. The students' major assignments are three group projects on the fabrication of a real component in each of the three material groups. The assignments are drawn from current naval projects such as floating docks, utility boats, foundation piles, floating drydocks and aids-to-navigation markers.

An important part of each project is a "reality check" calculation of the preliminary design. The groups of three to four students interact with the project sponsors and develop a 15-20 page report presenting a preliminary design and fabrication process. The sponsor along with the naval design agent and the instructor grade the projects. Each project is selected so that the preliminary design calculations can be easily handled by a senior undergraduate, freeing the student to concentrate on the fabrication. The goal is to give the students the feel for fabrication issues and to learn simple "reality check" calculations to ensure that the final part will be in the ballpark for its intended use.

Figure 6 is a sketch of the group project given to the students in the spring of 2000. The design was for an 18-foot fiberglass garvey to be used as a utility and coaching boat at the Naval Academy. The conceptual design was completed by the professor using the American Bureau of Shipping (ABS) Rules for Building and Classing Reinforced Plastic Vessels (1978) and "Fiberglass Boat Design and Construction" by Robert Scott, 1996. The students were tasked with developing the preliminary design and process for fabricating 20 vessels at the Annapolis Naval Station facility. Four of the six groups chose female molded, resin-infusion, vinyl ester/E-glass laminates based on a series of tests performed at the Naval Academy[4]. One group chose low temperature epoxy prepregs and one chose a wet layup epoxy laminate. Three groups increased the laminate thickness due to a belief the vessels would see greater impact loads then those anticipated by the ABS Rule. Each group submitted proposed shop layouts of the Hangar Building at the Naval Station to most efficiently produce the vessels, and quality control and material specifications were included in their reports. While not sufficient for actual production, the 15-20 page documents were sufficient for bid purposes and indicated the students learned the fundamentals of a composite fabrication technique common to the Navy.

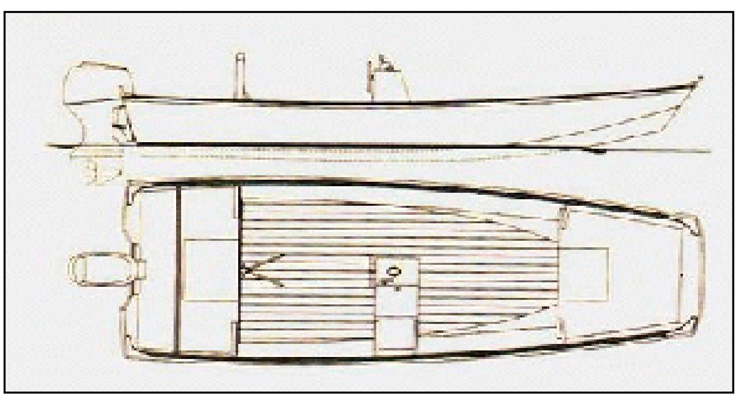


Figure 6. Eighteen foot garvey design used for composite group project.

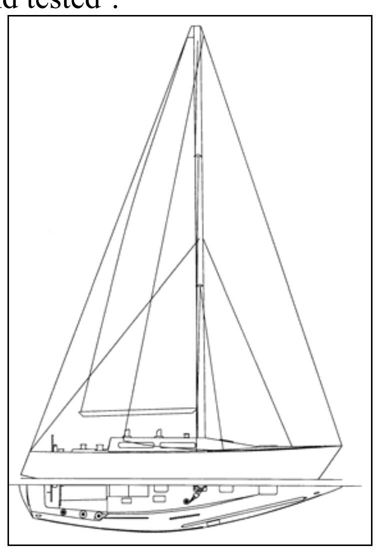
Feedback from the students on the teaching evaluation forms has been universally positive. The combination of hands-on fabrication and quality assurance testing combined with the application of their learned design skills has been extremely popular. The course has been oversubscribed each time it was offered. Changes over the four years include more emphasis on spreadsheets for the calculations rather than specialized programs, more emphasis on non-destructive evaluation testing to reflect practice in the fleet, and providing specific examples of the report coverage and format desired. The current grading distribution includes 45% for the three projects, 20% for the midterm, 25% for the final and 10% for homework.

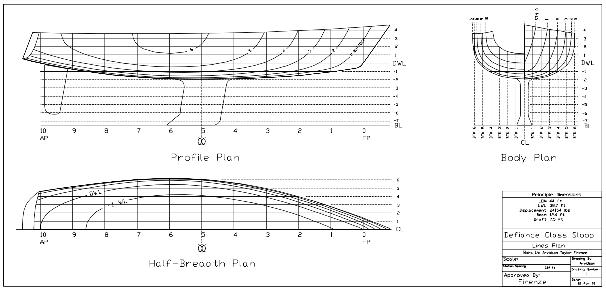
EN471 – Ship Design 1 and EN476 – Ship Design 2

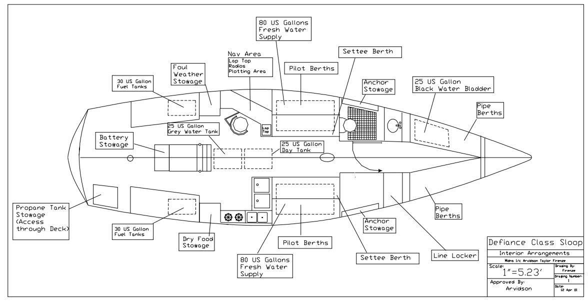
The two naval architecture capstone courses provide the student the opportunity to apply all the information learned through earlier courses. The first course provides the final information required to perform a preliminary design of a small monohull. The (2-2-3) course includes an introduction to regulatory and classification society rules and parametric mission criteria development. Each student produces a preliminary design for a set design criteria. Seventy five percent of the course grade is based on the design package.

The second capstone course is a unique (0-6-3) format with no lectures. The students' entire time is devoted to developing a preliminary design of their choice. The students determine the mission criteria, loads, structures, piping, electrical, powering, arrangement and other requirements. In front of an industry panel they present their project as if they were responding to a bid request. One hundred percent of their grade is based on the presentation and design package.

An example is illustrated below. Early in the 2001 academic year the USNA announced that it would acquire new 44-foot sail training craft and midshipmen were invited to participate in the design process. Three naval architecture seniors participated and used that background to develop their capstone design. Figures 7-10 show three of their drawings and the tank model they built and tested[5].







Figures 7-10: Capstone design course project submissions, including sail plan, tank test photo, lines plan, and accommodations plan.

Their research pointed out numerous potential areas for improvement in the actual vessel and many of their design solutions were incorporated into the final design of the new Navy 44 Sail Training Craft[6].

Conclusion

The use of project-based design in naval architecture courses at the USNA has proven to be a successful way to introduce students to the fundamentals of their discipline and to provide an enjoyable way to learn. Courses in each of the students' three years in the major include significant projects, starting with a simple balsa tank model and culminating with a complete preliminary design. It is interesting to compare Figures 3 and 7 and see the progress the students made in just two years.

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Biographical Information

PAUL H. MILLER is an Assistant Professor in the Naval Architecture Program at the USNA and received a B. S. in Mechanical Engineering from Tufts University in 1985 and a M. E. in Ocean Engineering from Stevens Institute of Technology in 1987. In 1994 he completed a M. E. in Naval Architecture and in 2000 he completed a D. Eng. in Civil Engineering from the University of California at Berkeley. His research focus is on marine composites.

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