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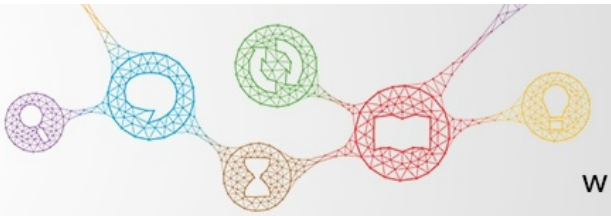

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Research through education: training yacht designer by a cross curricular learning-by-doing strategy

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ABSTRACT

This paper presents an innovative educational project which improves traditional yacht design programs by mixing up the design, prototyping and construction phases. The foundations of this educational project have been laid down during several years of management of the master in Yacht Design at the Politecnico di Milano. This new didactic model is characterized by high interdisciplinarity and strong interaction among the stages of ideation and development. Furthermore, it aims to train professionals to meet strict deadlines and to respect the natural work flow of a project. The model has been tested in 2016 in the LDYD Learning-by-doing Yacht Design Workshop.

The workshop involved professors, researchers and students of different departments: Design, Aerospace, Chemistry and Mechanical Engineering. The participants shared their knowledge by designing and building a 4,60m high-performance sailing-boat to take part in a competition within Italian Universities, called 1001velaCup. It consists of two different challenges, a regatta and a towing tank test, to evaluate the performance of the different boats. The workshop provided the tools to manage the design and construction processes of boats – general plans, ergonomics of navigation, aero-hydrodynamics of hulls and sails, and deck equipment – within the strict deadline of the regatta. Alongside a training result, the workshop stimulated the research activity and favoured the consolidation of the partnership within the university and the industry.

The new didactic model, enriched by the academic results obtained from the LDYD workshop, will be implemented next year into interdepartmental courses.

Keywords: design education; cross-curricular education model; yacht design; learn by doing; yacht construction techniques.

INTRODUCTION

The broad field of educational and training in design is in rapid evolution. The potential of new technologies creates many challenges. These trends not only have a strong impact on design and development approaches in research and professional practice, they also affect the aims, content and processes of learning. Design research in educational strategies and training of professionals is moving on a learn-by-doing approach, with a construction of innovative solution in collaboration with the design studios and industrial companies (1) (2).

The purpose of this article is to present and discuss an innovative educational project which improves traditional yacht design programs by mixing up the design, prototyping and construction phases of a sailing boat.

Yacht design is an applied sector of industrial design characterized by a particular complexity. The students involved in this field need to coordinate highly diversified areas of competence: engineering, design, architecture, ergonomics and materials, with their respective specialized

disciplinary articulations. Because of this, every project has to manage the diversified system of limitations imposed by the rules, by the user and by the overall efficiency of the system-boat.

For these reasons, the director board of the master in Yacht Design at the Politecnico di Milano starts to investigate an alternative didactic model to teach yacht design principles simultaneously to designers, architect and engineer. The opportunity to participate in the university challenge 1001vela cup, stimulate this research on training professionals. 1001vela cup is an athletic and educational initiative fostered by Italian universities and it consists of two different challenges, a regatta and a towing tank test, to evaluate the performance of hi-performance sailing boats designed, built and race by university students.

In the following chapters, the new teaching program is presented with activities description, objectives and expectations. Then, the 1001velaCup challenge is introduced and the LDYD Learning-by-doing Yacht Design Workshop dealt at Politecnico di Milano presented. Finally, the outcomes and teaching results of the yacht design workshop are outlined concurrently with the future activities to be done.

2. Yacht Design Cross-Curricular Learning-By-Doing Strategy

A Yacht Design project involves highly diversified fields including engineering, design, architecture, ergonomics and materials science, and their respective specialized disciplinary articulations. It has to manage the diversified system of limitations imposed by the rules, by the user and by the overall efficiency of the system-boat.

Students approaching this field in the Master in Yacht Design at the Politecnico di Milano generally have different background: architecture, design or engineering curricula. Because of this, the master direction board develops an innovative didactic model to teach the yacht design principles, naval architecture ad boat construction through a workshop experience. The cross-curricular learning-by-doing strategy is expected to have a positive effect in learning because “it teaches implicitly rather than explicitly” (1). It helps to manage the complexity of a yacht project putting in relation all the specialized fields of study. In order to make classrooms into learning-by-doing experiences, workshop and prototyping experiences will be carried out. A multidisciplinary approach, together with the system of design methods and tools, offers to the teaching activity a useful contribution to managing the project design process.

This new didactic model combines the yacht design spiral process (3) with the double diamond model (4). It is characterized by high interdisciplinarity and strong interaction among the stages of research, ideation, development and prototyping phase. Furthermore, it aims to train professionals to respect the natural work-flow of a project and to meet strict deadlines.

The model presents four main stages across a spiral. Each of the four stages crosses multidisciplinary topic – boat requirements, proportion, weight and powering, water-lines plan, hydrostatic and aero-hydrodynamics, sail plan, construction materials and construction techniques, structure definition, deck plan, keel and rudder design, and cost management – gradually increasing complexity. These stages are Discovering, Define, Develop and Deliver, according to the double diamond model.

Discover: identify, research and understand the initial problem. The first quarter of the spiral marks the start of the project. This begins with an initial idea or inspiration, often sourced from a discovery phase in which user needs are identified. Key activities and objectives during the Develop stage are: target identification, market and user research, yacht characteristics’ comparison.

Define: focus on and develop a project. The second quarter represents the definition stage, in which interpretation and alignment of these need to project objectives is achieved. Key activities during the Define stage are: concept and project development, project management, hull and deck design, sail plan design and appendages setting.

Develop: design the solution, ready the concept for production. The third quarter of the spiral marks a period of development where design solutions are developed, iterated, engineered and tested. Key activities and objectives during the Develop stage are: design engineering, construction materials and equipment tests, costs and resources management.

Deliver: prototyping, launch, test and evaluate. The final quarter represents the delivery stage, where the resulting project is prototyped. The key activities and objectives during this stage are: prototyping and/or construction experiences, launch, testing, evaluation and feedback loops.

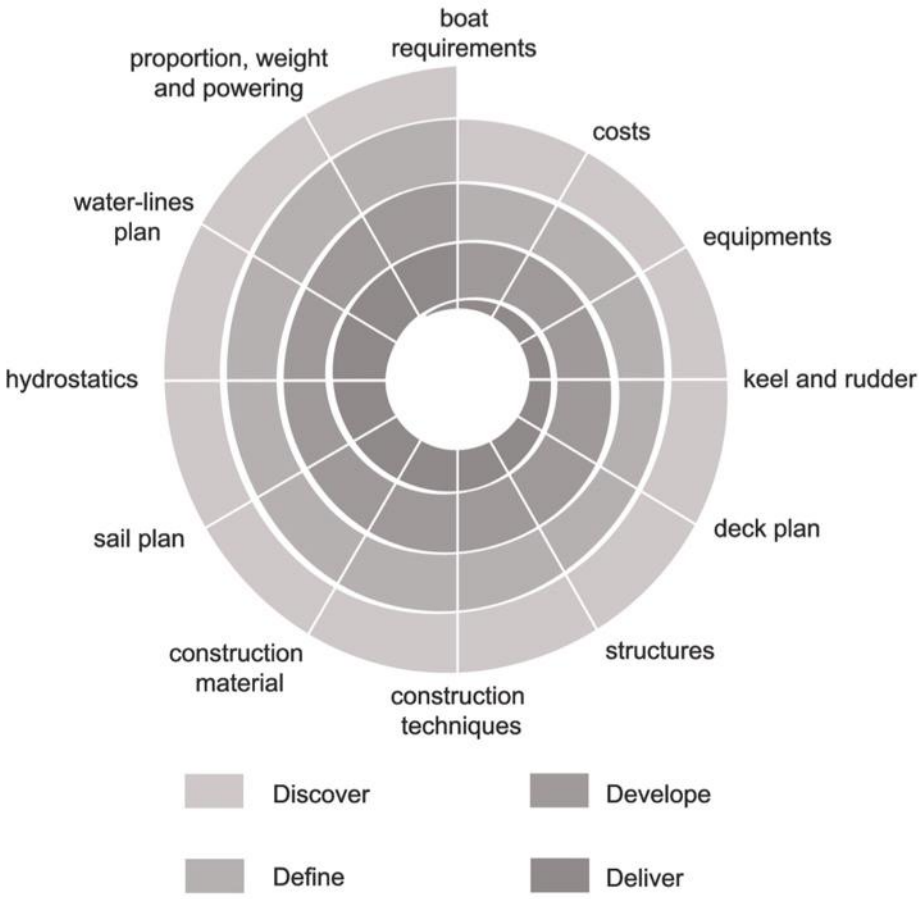

Fig.1: Yacht Design cross-curricular learning-by-doing model

3. Design And Teaching Challenge At 1001 Vela Cup

The teaching model presented has been tested in the academic year 2015-16 at the Yacht Design master program within the LDYD Learning-by-doing Yacht Design Workshop. This cross-curricular master degree course involved professors, researchers and students of different departments: Design, Aerospace Engineering, Chemistry and Material Engineering, and Mechanical Engineering. In the LDYD Learning-by-doing Yacht Design Workshop, the participant shared their knowledge by designing and building a 4,60m high-performance sailing boat, skiff-boat, to take part to the 1001vela cup competition. The 1001vela cup challenge took place in Venice in September 2016 as a regatta race and in Naples in February 2017 as a towing test race.

3.1. 1001 Vela Cup

1001 vela cup is an athletic and educational initiative fostered by University Roma Tre since 2008. It consists of two different challenges, a regatta and a naval tank test, to evaluate the performance of hi-performance skiffs built by university students. The event is open to Italians and foreign universities with the aim to compare and to share educational programs, know-hows, and research results of the participants. At present, the universities involved are thirteen: Politecnico di Milano, Università di RomaTre, Università La Sapienza, Università di Firenze, Università Alma Mater di Bologna, Università di Padova, Polo Universitario di La Spezia, Università di Bari, Università di Palermo, Università di Messina, Università di Trieste, Università di Catania and Politecnico di Torino.

The starting point of the 1001 vela cup challenge is the class rules R3, designed to develop research on high-performance boat and sustainable materials and construction techniques. The regulation requires that these boats are designed and manufactured within university programs and respecting the R3 class box rule: 4.60 meters in length maximum by 2.10 meters of beam, 33 sqm of sail area, 70% minimum of natural or recycled material for the hull and deck construction. By means of different educational paths, each school started design activities and prototyping laboratories aimed at the construction of the boats, following the R3 class rules. During the years, twenty-five sailing boats were constructed and took part to regattas and towing tank test to compare at sea and in the laboratories the boat performances.

Both regatta races and towing tests play a key role in the research activity promoted by 1001vela. Students and researchers are direct involved in the sail test of the constructed skiff. The test results are directly comparable each other stimulating the further development of the research activities itself.

Fig.2: R3 skiff involved in a regatta race in Venice, September 2016

Fig.3: R3 skiff involved in a regatta race in Venice, September 2016

Fig.4: Politecnico di Milano skiff "Bauscia" involved in the towing test in Naples, February 2017

The capacity of 1001 vela cup to promote and to develop research and teaching activities is verified with the number of students involved that are now professional in the yachting sector. Over the years, professional outcomes have included designers and naval engineers in specialist design studios, project and production managers, quality-control supervisors, and professional sailors, including Olympic ones.

Alongside educational comparisons, an opportunity offered by the initiative is the development of applied research activities which could be transferred to the yacht industry. Innovative applications of environmentally sustainable composite materials using natural fibers, such as flax, cork, hemp, and basalt are carried out in partnership with industrial companies favoring the consolidation of the relationship between the university and the boating sector.

3.2 The LDYD Learning-by-doing Yacht Design Workshop

The Learning-by-doing Yacht Design Workshop was carried out in the academic year 2015-16 at the Yacht Design master program of Politecnico di Milano and represented the first finalized test of the didactic model presented. The workshop involved professors, researchers and students of different departments: Design, Aerospace Engineering, Chemistry and Material Engineering, and Mechanical Engineering. The project team was composed by 15 master course students (5 designer, 2 architects, 3 aerospace engineers, 3 mechanical engineers and 2 chemistry and material engineer), 2 professors, 2 researchers in the field of yacht design and naval architecture and 2 laboratory technicians. A student and a researcher were selected as project managers of the workshop, while the other participants were divided into three different teams: R&D, Sailing and shore team.

According to the teaching model presented, the workshop was divided into four different stages: Discover (research), Define (concept ideation), Develop (design engineering) and Deliver (prototype/construction phases). The research, ideation and design engineering stages were developed in the master in Yacht Design classroom whereas the construction phase, including the systems and equipment prototyping, was carried out with the support of Lecco Innovation Hub - SMaRT lab, the university laboratory on sustainable marine research on technologies. The project work teams were not divided into tasks but each student participated in all the workshop processes sharing their previous knowledge in the field of design or engineering. Furthermore, they had to manage time and budget resources, sponsorship, training sections and 1001vela cup racing activities.

Through a direct hull and sail-plan analysis, sailing performances, ergonomics features and usability, the workshop team built the skiff project based on the spiral process of yacht design. Then CFD analysis was performed in order to define the proper shape of hull, appendages and sails. The design-engineering phase was characterized by high interdisciplinarity and strong interaction among the different workshop teams. The main challenges were the definition of a bio-composite lamination plan based on a sandwich structure of flax fibers, cork core, and styrene-free epoxy resin as the matrix, balancing weight, mechanical proprieties and production technologies.

The result of these first phases was the design of a skiff, a high-performance sailing yacht. According to the R3 box-rule the boat, called Bauscia, is 4.60 meter in length by 2.10 meter of beam and 33 sqm of sail area. To reach 70% of natural construction material, the team projects designed a bio-composite hull, a sandwich wooden deck of balsa and marine plywood and terraces made of bamboo. Mast, boom, and sail equipments were made of aluminum alloy, while the appendages were made in fiberglass with balsa as core and bowsprit in carbon fiber composite.

The Bauscia construction phase took two months following four different steps: 1) vacuum infusion lamination of the hull, 2) hull structures and reinforcement, 3) deck construction and 4) equipment, including keel, rudder and sailing plan. This was the opportunity to verify all the design features and to take into practice all the research developed during the workshop period. Moreover, the construction phase was the occasion to teach the proper characteristic of the construction materials and the work flow of the different technology.

Fig.5: Hull reinforcement fibers and core placement in the female mold

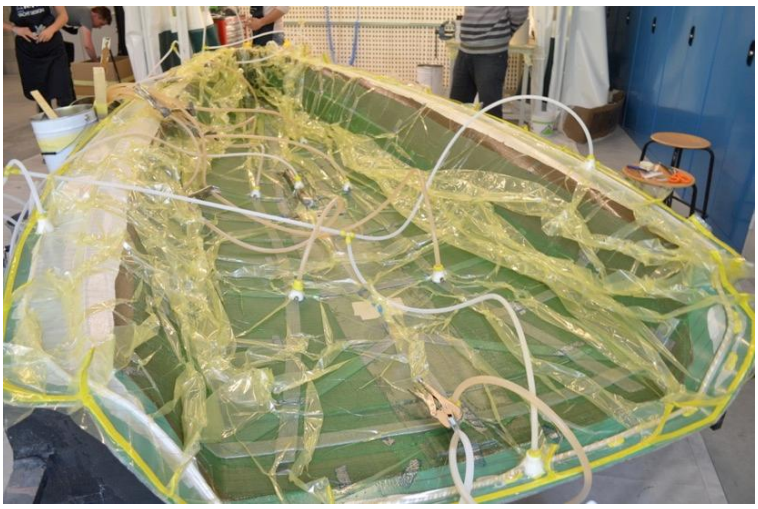

Fig.6: Hull vacuum infusion process

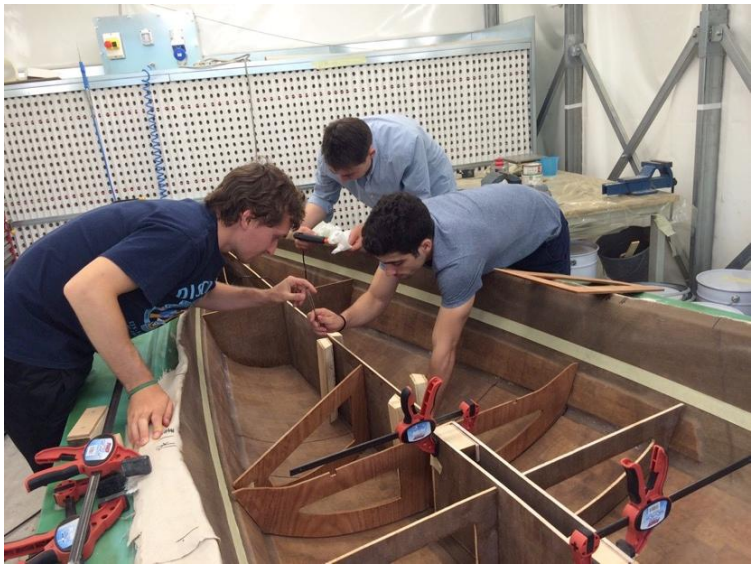

Fig.7: wooden structures in place before their lamination

Fig.8: Launch of Bauscia skiff

4. Workshop Results And Future Activities

Bauscia came second at the regatta race and third in the performed towing test. The results of these challenges are considered as a starting point for the future skiff design activities within the 1001vela cup program.

The didactic model presented and developed in the LDYD Learning-by-doing Yacht Design Workshop provided the tools to manage the design and construction processes of boats – general plans, ergonomics of navigation, aero-hydrodynamics of hulls and sails, and deck equipment – within the strict deadline of the regatta. The workshop offered the opportunity to simulate shipyard professional dynamics and to promote relations with external stakeholders (materials and technologies suppliers, sponsors and athletes). Activities and design choices were strategically planned, respecting the evolution of the project and the construction time and techniques. Through a learning-by-doing approach, the workshop provided tools to develop and manage project solutions respecting economic and technological sustainability.

Furthermore, the workshop stimulated the research activity and favoured the consolidation of the partnership within the university and the industry. Bio-composite materials and high-performance sail plan were carried out in relationship with industrial partners fostering the research on design for sustainability.

The new didactic model, enriched by the academic results obtained from the LDYD workshop, will be implemented next year into interdepartmental courses within the Politecnico di Milano school of Design and the master degree program of Mechanical and chemical engineering. The university course will be structured in four integrated modules (principles of yacht design, structure and hull design, composite material techniques, aero-hydrodynamics of sailing) and a final workshop to prototype the project results.

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