

## Article

# Research–Teaching Nexus in Electronic Instrumentation, a Tool to Improve Learning and Knowledge of Marine Sciences and Technologies

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**Abstract:** In higher education institutions, there is a strong interaction between research and teaching activities. This paper presents a case study on the research–teaching nexus based on an analysis of academic results related to the course “Instrumentation and Data Analyses in Marine Sciences” within the Marine Sciences and Technologies Bachelor’s Degree at the Universitat Politècnica de Catalunya (UPC), taught at the Vilanova i la Geltrú campus (Barcelona, Spain). The start of this degree in the academic year 2018–2019 allowed the assignment of technological subjects in the degree to a research group with extensive experience in the research and development of marine technologies. The first section of this paper aims to provide a justification for establishing the Marine Sciences and Technologies Bachelor’s Degree. It highlights the necessity of this program and delves into the suitability of the profiles of the professors responsible for teaching marine technology subjects. Their entrepreneurial research trajectory and their competence in electronic instrumentation are strong arguments for their appropriateness. The next section of the paper explores a detailed analysis of academic results based on surveys and student performance indices. Through a thorough examination of these data, this case study demonstrates, within the context of all UPC degrees, that assigning a research group made up of experienced professors and researchers in the field who are accustomed to working as a team produces superior academic results compared to assignments to professors who do not work as a team. Teamwork presents specific skills necessary for operating the infrastructures and equipment associated with an experimental degree.

**Keywords:** higher education; science–technology symbiosis; marine technology; research group; electronic instrumentation; thinking skills



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## 1. Introduction

To support endeavors aimed at minimizing ocean degradation and bringing together global actors within a shared framework that ensures optimal conditions for sustainable ocean development, the United Nations has declared a decade of ocean science for sustainable development (2021–2030), known as “The Decade of the Ocean”. Hosted by Spain and co-organized with UNESCO’s Intergovernmental Oceanographic Commission (IOC/UNESCO), the 2024 UN Ocean Decade Conference took place on 10–12 April 2024 in the city of Barcelona [1]. At this conference, ten challenges for the Decade of the Ocean were proposed for collective impact. These included the study and mitigation of marine pollution; the preservation of biodiversity and ecosystems; sustainable nutrition for humanity; the implementation of a sustainable and equitable ocean economy; the enhancement of community resilience to climate change; the expansion and enhancement of the global

ocean observing system; the augmentation and improvement of the global ocean observing system through shared databases and field instrumentation; and the dissemination of knowledge and technology to ensure a broader understanding of the ocean.

The ocean, as the Earth's largest component, plays a crucial role in stabilizing the climate and sustaining life on Earth, thereby impacting human well-being. However, the First World Ocean Assessment in 2016 highlighted that a substantial portion of the ocean is facing severe degradation, with projections indicating a potential exacerbation of this situation if no intervention occurs, as the global population is anticipated to reach 9 billion by 2050 [2].

There is an urgent need for science-backed adaptation strategies and policy responses to address climate change. In accordance with the directives of the United Nations General Assembly, the Intergovernmental Oceanographic Commission (IOC) of UNESCO is spearheading the preparatory process for the decade. This initiative aims to foster international collaboration in marine sciences to enhance the governance of the ocean, coasts, and marine resources [3].

The IOC supports member states and scientific collaborators in establishing global systems for monitoring the dynamic ocean. The Global Ocean Observing System (GOOS) comprises various entities providing countries and end-users with crucial information on essential physical, chemical, and biological ocean variables, essential for assessing ocean health. The International Oceanographic Data and Information Exchange (IODE), initiated in 1961, facilitates the exchange of oceanographic data and information among member states. The Ocean Biogeographic Information System (OBIS) serves as a global data platform that integrates, performs quality control, and offers access to over 100 million occurrence records of 160,000 distinct marine species. The General Bathymetric Chart of the Oceans (GEBCO) is dedicated to mapping the entire ocean floor. The Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) collaborates with the Global Sea Level Observing System (GLOSS) to provide information supporting long-term climate change studies [3].

In global sustainable development, universities worldwide, including those in Europe, play a pivotal role. The European University Association aligns with the global agenda to achieve the United Nations' Sustainable Development Goals (SDGs). Universities contribute to these objectives through research and education across diverse disciplines, fostering the potential for a better future. A university must embrace three core missions: teaching, research, and societal service. This entails not only imparting knowledge through education but also generating new knowledge through research and disseminating it to society through knowledge exchange for innovation [4].

At the governance level, the Government of Catalonia has drawn up the Catalonia Agenda, an action plan that involves a series of actions from 2016 to 2030 with the aim of promoting the sea as a source of progress in Catalonia, on a par with the most prosperous economies in Europe. This agenda has entailed the strategic elaboration of the Maritime Action Program in 2016 and the promotion of BlueNetCat, the transfer and innovation instrument of the Government of Catalonia in Blue Economy [5,6]. These steps have made Catalonia a region that points towards the sea as a source of knowledge and progress. At an economic level, Catalonia can offer outstanding companies in various fields such as port logistics (e.g., Port de Barcelona and Port de Tarragona), marine instrumentation, robotics and engineering (e.g., GPA Seabots, Triton Submarines, Ictineu Robotics, or Smalle technologies), shipbuilding and repair (e.g., Marina Barcelona 92 and Bound4Blue), operational oceanography and marine resource management (e.g., Tecnoambiente), or coastal restoration and nature-based solutions (e.g., Ocean Ecostructures, Underwater Gardens International, or Ona Futura). This variety of companies and working fields makes Catalonia an ideal place to develop a career in the marine sciences [5].

All of the above lead to the conclusion that in Catalonia there is a solid ecosystem with important future prospects in different areas of the blue economy, especially those related to marine sciences and technologies (sea fishing, aquaculture, port activities, naval

construction, the manufacture of instruments and measuring devices, transport maritime, etc.). In the year 2019, *the Blue Economy* in Catalonia involved about 25,000 million euros, more than 38,000 companies, and 200,000 jobs [6]. Catalonia has an increasingly mature research, transfer, and innovation ecosystem with research centers, universities, and private companies working in several of its sectors. Marine Science Research in Catalonia is represented by the Maritime R+D+i Network of Catalonia (BlueNetCat) which hosts more than 800 members including researchers, trainees, and research technicians from more than 70 research groups from seven public universities (UB, UAB, UPC, UdG, URV, CSIC, and IRTA). The aim of BlueNetCat is to incubate and accelerate Catalan scientific and technological projects in the blue economy for private companies and public administrations [6].

In this overarching context of the sustainable development of the oceans, to cover the *challenges of the Ocean Decade* and the needs of the *Blue Economy*, it is essential to have highly qualified personnel with an entrepreneurial profile. Thus, this paper examines the research–teaching nexus in electronic instrumentation, using the learning and knowledge of Marine Sciences and Technologies as a case study. In response to concerns about climate change in the marine environment, it is crucial to explore the potential contributions of the academic world to the development of tools for sustainable global practices. In line with this objective, the Universitat Politècnica de Catalunya (UPC) has launched a new academic degree, the Bachelor’s in Marine Sciences and Technologies. The main goal of this degree program is to provide comprehensive training to professionals, enabling them to conduct advanced research and offer expert advice on the use of various marine resources, environmental and climatic complexities, and the impacts of human activities on marine and coastal ecosystems.

## 2. University Context Where the Transfer of Knowledge Related to the Marine Science Takes Place

In this section, we first provide a general overview of the types of university degrees related to marine sciences and technologies, detailing those offered by Spanish universities. Subsequently, as a case study, we focus on the Bachelor’s in Marine Sciences and Technologies offered by UPC, specifically on the technological specialization from the third year of the academic program. Finally, in the third subsection, drawing from the course guide, we present the main skills, general objectives, and the most relevant content of the courses in the marine technologies specialization.

### 2.1. Classification by the Content of the Curricula of University Degrees Related to Marine Sciences and Technologies

Degrees related to the marine environment can be broadly categorized into two main groups. The first is oriented towards fundamental sciences such as biology, geology, and oceanography, falling under the broader field of Marine Science (e.g., Master of Science in Ocean Engineering/Marine Science). The second category is linked to engineering applications in the marine environment, encompassing various thematic areas. *Marine Construction and Platforms* includes technologies related to the ocean floor, logistics, and the management of port infrastructures (e.g., Marine Technology/Marine Technology with Marine Engineering). *Aquaculture and Fisheries Resources* focuses on biological aspects and industrial exploitation (e.g., Aquaculture and Fisheries Resources). The *Renewable Energies* category explores renewable energy sources with a specific emphasis on marine energy.

These distinct lines of study within marine-related degrees offer students a comprehensive understanding of both the scientific and engineering aspects of the marine environment, catering to various interests and career paths. However, an examination of various university degree programs related to the marine environment [7–9] reveals a notable gap in the comprehensive integration of both scientific principles and the design of equipment and instrumentation systems. A noteworthy exception to this trend is observed in the collaborative efforts of MIT and Woods Hole, as evidenced by their joint master’s program, “Applied Ocean Science & Engineering” [10]. In the context of Spain, university degrees are oriented towards fundamental sciences such as biology, geology, and oceanog-

raphy. These Marine Sciences degrees, with very slight content differences, are offered by five public institutions. The Faculty of Science at the University of Alicante, the Faculty of Earth Sciences at the University of Barcelona, the Faculty of Marine and Environmental Sciences at the University of Cadiz, the Faculty of Marine Sciences at the University of Las Palmas de Gran Canaria, and the Faculty of Marine Sciences at the University of Vigo, and one private faculty. The Catholic University of Valencia Saint Vincent Martyr, Faculty of Veterinary and Experimental Sciences, also offers a related program. However, it is noteworthy that none of these programs currently addresses technological aspects such as the design of equipment and instrumentation systems, deficiencies that have prompted the UPC to propose a new degree. More broadly, Table 1 shows a sample of different programs related to Marine Sciences and Technologies, where Spanish universities have also been included. In Table 1, the selection of the various universities has been focused on those whose undergraduate studies are most closely related to the Marine Sciences and Technologies degree proposed in the presented work. Additionally, a global perspective has been provided by including some leading universities in Marine Sciences and Technologies from different continents and countries, based on rankings of the best universities such as the Times Higher Education (THE) World University Rankings, the Academic Ranking of World Universities (ARWU), and the QS World University Rankings.

**Table 1.** Small sample of universities around the world offering degrees in Marine Sciences and Technologies.

Country	University	Focus of Programs
United States	Scripps Institution of Oceanography	Marine Biology, Oceanography, Marine Chemistry, and Geological Oceanography
	Woods Hole Oceanographic Institution (WHOI)	Joint Program with MIT in Oceanography and Applied Ocean Science and Engineering
	University of Washington, School of Oceanography	Oceanography (Physical, Chemical, Biological, and Geological)
Canada	Dalhousie University	Oceanography (Chemical, Physical, and Biological)
	Memorial University of Newfoundland	Marine Environmental Technology, Fisheries Science, and Marine Engineering
United Kingdom	University of Southampton	Oceanography, Marine Biology, Marine Geology, and Maritime Engineering
	University of Plymouth	Marine Biology, Oceanography, Marine Conservation, and Maritime Business
	Newcastle University	Marine Technology
Australia	University of Tasmania	Marine Biology, Oceanography, Fisheries Management, and Antarctic Studies
	James Cook University	Marine Biology, Marine Science, Aquaculture, and Environmental Science
Singapore	National University of Singapore (NUS)	Offshore Engineering
Japan	Tokyo University of Marine Science and Technology	Marine Biosciences, Marine Engineering, and Ocean Policy
Xina	Xiamen University	Marine Biology, Oceanography, Marine Chemistry
South Korea	Korea Maritime and Ocean University	Naval Architecture and Ocean Engineering, and Marine Engineering
Netherlands	Delft University of Technology	Marine Technology
Norway	University of Bergen	Marine Geology, Oceanography, and Climate Studies
	Norwegian University of Science and Technology	Marine Technology
Sweden	Chalmers University of Technology	Naval Architecture and Ocean Engineering
Germany	Alfred Wegener Institute for Polar and Marine Research	Marine Biology, Oceanography, and Marine Geology

Table 1. Cont.

Country	University	Focus of Programs
Spain (Marine Sciences)	-Universidad Católica de Valencia San Vicente Mártir (UCV), Facultad de Veterinaria y Ciencias Experimentales	
	-Universidad de Alicante (UA), Facultad de Ciencias	
	-Universidad de Cádiz (UCA), Facultad Ciencias del Mar y Ambientales	
	-Universidad Las Palmas Gran Canaria (ULPGC), Facultad de Ciencias del Mar	
	-Universidade de Vigo (UVigo), Facultade de Ciencias do Mar	
Spain (Marine Sciences and Technology)	-Universitat de Barcelona (UB), Facultat de Ciències de la Terra	
	-Universitat Politècnica de Catalunya (UPC), Escuela Técnica Superior de Ingeniería de Caminos, Canales y Puertos de Barcelona, Escola Politècnica Superior d'Enginyeria de Vilanova i la Geltrú (EPSEVG), Escola d'Enginyeria Agroalimentària i de Biosistemes de Barcelona (EEABB)	

A pivotal moment shaping the subsequent structure of the Spanish university occurred with the enactment of the University Reform Law (LRU) in 1983 [11]. Prior to 1983, instructional activities in Schools and Engineering Faculties were conducted by distinct chairs. The LRU introduced a transformative framework by establishing areas of knowledge that encompassed various disciplines and creating departments to consolidate professors teaching within these disciplines. In this matrix structure of academic centers and departments, academic centers assume the responsibility of proposing the Bachelor's/Master's degrees to be offered within their facilities. Following approval by university bodies, these proposals undergo accreditation by different educational administrations. Subsequently, the allocation of different subjects is entrusted to the departments within the corresponding knowledge area.

## 2.2. Bachelor's Degree in Marine Sciences and Technologies

The pursuit of excellence stands as a primary objective for all institutions of higher education, with the accreditation process serving as a key mechanism to attain this goal. Accreditation, recognized as a robust quality assurance tool, plays a crucial role in evaluating national higher education systems. It serves as an indicator of quality, signifying that an accredited institution/program has undergone a rigorous external evaluation conducted by peers, adhering to predefined standards and principles, and meeting specified requirements [12]. Accrediting bodies can take various forms, such as government organizations [13], professional engineering institutions, and independent accreditation boards (e.g., ABET—Accreditation Board for Engineering and Technology [14]), among others.

The Bachelor's Degree in Marine Science and Technologies has implemented a quality system ensuring a design, implementation, and development process aligned with the European Higher Education Area (EHEA). These studies have been positively evaluated by the Agency for the Quality of the University System of Catalonia (AQU) [15] through the AUDIT (derived from the Latin term “audire” and commonly used in Europe to refer to quality assessment processes in university institutions) project of the National Agency for the Evaluation of Quality and Accreditation of Spain (ANECA) [13].

Initiated in the academic year 2018–2019, the Bachelor's Degree in Marine Science and Technologies, registered in the Spanish Ministry of Education's degree register, spans four years and entails 240 ECTS (including the bachelor's thesis) [16]. The program offers in-depth studies in four major areas of knowledge related to the marine and coastal environ-

ment, including oceanography, marine technologies and biotechnologies, the conservation and sustainable management of marine resources, and the effects of climate change [17]. Under the auspices of the Barcelona School of Civil Engineering, with contributions from the Barcelona School of Agricultural Engineering (ESAB) and the Polytechnic School of Engineering of Vilanova i la Geltrú (EPSEVG), this degree is distinctive for involving three educational centers in its launch. The ETSECCPB serves as the reference center, managing all administrative documentation for the degree [17]. The degree program is structured into two distinct specializations. One in Marine Sciences and Engineering and the other in Marine Technologies. This work specifically focuses on the Marine Technologies specialization, concentrating on the curriculum offered at the Vilanova Campus of UPC [17].

The SARTI group, given its experience in marine technologies (see Section 4), has been involved from the beginning in proposing the curriculum for the Bachelor’s in Marine Sciences and Technologies. In its implementation, SARTI has managed the teaching guide for the different subjects related to the technological intensification of the Marine Sciences and Technologies degree. This academic proposal incorporates recent advancements in acoustics, electronics, and robotics, focusing on scientific aspects and the design of equipment and instrumentation applied to marine observation and data acquisition. This specialization is crucial for evaluating the quality of oceanic parameters in the current context of climate change, as previously outlined in the Introduction section [4]. Table 2 outlines the subjects taught in the second quarter of the third year and the first quarter of the fourth year for the Marine Technologies specialization.

**Table 2.** Marine Sciences and Technologies subjects at Vilanova Campus–UPC.

Subject Name Six ECTS Credits	Year	Theory Hours	Laboratory Hours	Self-Learning Hours	Specialty
Instrumentation and Data Analyses in Marine Sciences	3Q2	30 h	30 h	90 h	Marine Sciences and Engineering/Marine Technology
Remote Sensing and Sensors	3Q2	28	32	90	Marine Sciences and Engineering/Marine Technology
Marine Survey, Acoustics and Sonar Systems	4Q1	30	30	90	Marine Technology
Instrumentation, Marine Robotics, and Power Systems	4Q1	28	32	90	Marine Technology
Platforms, Observatories, and Technologies of Marine Materials	4Q1	30	30	90	Marine Technology
Data Management: Communications, Programming, and Simulation	4Q1	21	39	90	Marine Technology

*2.3. Teaching Guide for the Mention in Marine Technologies Developed at the Vilanova Campus (EPSEVG)*

This section will present the main skills of the Marine Technologies specialization, the general objectives, and the most relevant contents of the subjects within the Marine Technology specialization of the Bachelor’s in Marine Sciences and Technologies (Table 3). Finally, the applied academic evaluation tools will be introduced. This allows for an overview of the teaching commitment of the SARTI research group, the author of the curriculum proposal included in the teaching guide [17].

**Table 3.** Contents of the subjects taught at the Vilanova campus.

Contents	Theory	Laboratory
<b>Instrumentation and Data Analyses in Marine Sciences</b>		
Introduction to marine instrumentation systems	4 h	
Characteristics of the instrumentation used in measurement systems	4 h	
Instruments for measuring meteoceanographic parameters	12 h	24 h
Electronic systems associated with instrumentation	4 h	
Data time series processing	6 h	6 h
<b>Remote Sensing and Sensors</b>		
Introduction to electronic measurement systems	3 h	
Sensor characteristics	3 h	
Sensors for measuring temperature, force and displacement	6 h	5 h
Sensors for measuring hydrographic properties	6 h	9 h
Sensors for measuring dynamic properties	6 h	10 h
Hydrophones and geophones	2 h	4 h
Introduction to satellite scanning systems	2 h	
Work presentation		4 h
<b>Marine Survey, Acoustics, and Sonar Systems</b>		
Basics of bioacoustics	30 h	
Cetacean classification		22 h
Management of communications with hydrophones: data, metadata, and registration		4 h
Evaluations		4 h
<b>Instrumentation, Marine Robotics, and Power Systems</b>		
Introduction to marine robotics	2 h	
Marine Robot Hardware	2 h	4 h
Kinematics of mobile robots	2 h	4 h
Perception	6 h	8 h
Location	4 h	4 h
Simultaneous mapping and localization—SLAM	4 h	4 h
Route Planning	4 h	2 h
Marine exploration through multiple mobile marine robots	4 h	6 h
<b>Platforms, Observatories, and Technologies of Marine Materials</b>		
Marine materials technologies	14 h	
Marine platforms and observatories	12 h	
Components and technical specifications of the elements that make up an observatory	4 h	
Field and laboratory activities; Mooring design		26 h
Evaluation tests; guidelines for marine observatory design		4 h
<b>Data Management: Communications, Programming, and Simulation</b>		
In the observation of marine parameters, introduction to information systems; communications networks	5 h	
Internet; TCP/IP protocol stack	2 h	1 h
Wired and Wireless networks: buses and Ethernet; GNSS	3 h	5 h
Variables, expressions, and errors; strings, lists, and dictionaries	2 h	6 h
Conditional, execution, and iteration	1 h	3 h
Libraries and functions; file operations; classes and objects	3 h	9 h
HTTP with Requests, Telegram, Pandas, and Matplotlib	3 h	11 h
Simulation modelling of communication systems	2 h	4 h

Skills to be achieved are as follows: *lexical and conceptual understanding* (acquire and apply terminology and concepts specific to Marine Sciences and Technologies); *the application of advanced methods* (apply cutting-edge methods and techniques in oceanography and

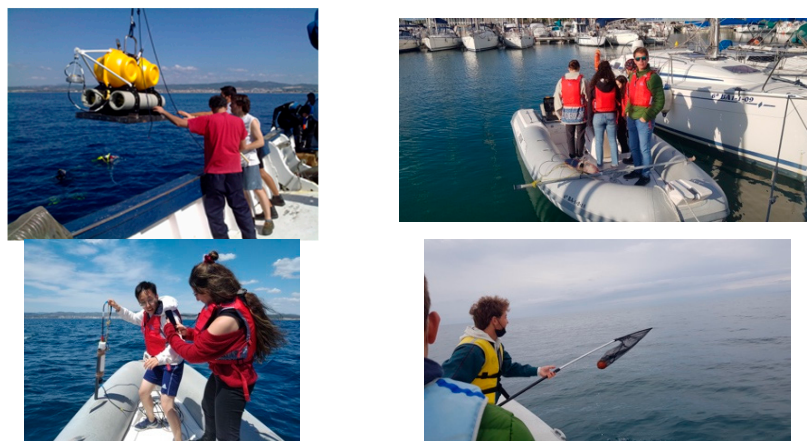
marine climate, encompassing physical, chemical, geological, and biological aspects); *the integration of techniques* (demonstrate the ability to integrate various numerical, laboratory, and field techniques to effectively analyze marine-related problems); *research planning and execution* (develop the capacity to formulate, plan, and carry out basic and applied research in the broad field of Marine Sciences and Technologies); *balance between conservation and economic activity* (promote sustainable practices that balance conservation efforts with economic activities, adhering to existing legislation and fostering social and environmental awareness); *the utilization of numerical and statistical techniques* (apply advanced numerical and statistical techniques in coastal and marine contexts for accurate data interpretation); *impact assessment and corrective measures* (use indicators to evaluate both natural and anthropogenic impacts, propose corrective measures, and implement monitoring and surveillance programs); *environmental studies and protection* (conduct comprehensive environmental impact studies, and manage and protect marine environments and adjacent coastal areas, including infrastructure and associated impacts); and *spatial and cartographic representation* (apply spatial and cartographic representation techniques to illustrate various environments at different scales) [17].

In the following paragraph, the general objectives proposed for each of the subjects in the Marine Technology specialization are presented (Table 2). Subsequently, a list of their contents with the allocation of hours for theory/practices is provided (Table 3).

The objectives are as follows: *Instrumentation and data analyses in marine sciences* (understand the methodologies for data collection and analysis in oceanography, learn about oceanographic measurement systems, and understand time series analysis methodologies in both time and frequency domains); *remote sensing and sensors* (understand the basic concepts of remote sensing, learn about the relationships between the physical/chemical characteristics of the marine environment, living resources, and remote sensing techniques, and learn about the characteristics and types of both active and passive remote sensing sensors); *marine monitoring, acoustics, and sonar systems* (learn about the mechanisms of acoustic wave transmission in the marine environment used in communication systems or sonar systems, introduce the modelling of the acoustic propagation channel and the effects of nonlinearities such as the Doppler effect or multipath, and know how to use and configure equipment for acoustic communication and exploration based on acoustic techniques); *instrumentation, marine robotics, and energy systems* (learn the basic principles of instrumental and robotic measurements in oceanography, communication with equipment, data acquisition, and processing, be capable of designing an energy system based on consumption requirements, learn about different types of underwater vehicles, and develop the ability to design and integrate the various components of an underwater vehicle); *platforms, observatories, and marine material technologies* (introduce the observation platforms used in oceanography, develop the ability to design and integrate each component of an observatory, introduce the technology and materials used in the construction of structures, and learn about common issues affecting materials used at sea); *data management, communications, programming, and simulation* (understand the most common communication buses and protocols in marine instrumentation, as well as the configuration for data reading and recording, develop the ability to design software applications for task automation, understand the operation of modelling and simulation tools applied to moorings, understand the characteristics of communication systems used in marine observation platforms, and know and use equipment and technology used in geolocation and data communication systems) [17].

The teaching methodology employed by the various instructional units for the subjects outlined in Table 2 is structured to include theoretical classes. During these sessions, professors present fundamental concepts and materials, offer examples, conduct exercises, and address problems. In smaller groups, fostering increased interaction with students, practical sessions are held in electronics and mechanics laboratories (refer to Table 3). Additionally, virtual campus ATENEA is utilized to provide targeted learning support materials and bibliography [18].

A notable aspect of the Marine Technologies specialization is the activities conducted at sea. Self-learning in these activities takes place near the OBSEA underwater observatory, located 2.5 nautical miles off the coast of Vilanova (Figure 1). The activities include planning small campaigns with the aim of acquiring various marine environment parameters, which involve data recovery and subsequent analysis of the obtained results, comparing them with those generated by the equipment at the OBSEA observatory. Some of the activities carried out have included deploying a CTD (conductivity, temperature, and depth) to measure water column temperature, using a drift probe to measure currents, conducting underwater sound measurements with hydrophone calibration/characterization, and performing bathymetries with an echo sounder.



**Figure 1.** Student activities on the sea.

Continuous assessment is integral to the subjects throughout the academic year. It involves diverse indicators gauged through assessment tests of individual and group activities conducted in the classroom, laboratory, and field. These assessment tests typically encompass questions related to the concepts aligned with the learning objectives of the subject and a series of application exercises. The Final Degree Project (TFG) is strategically positioned in the concluding phase of the study plan. It functions as a culmination, synthesizing the competencies acquired throughout the educational journey, and serves to evaluate the attainment of specific competencies associated with the degree [17].

### 3. Research vs. Teaching, Improving the Quality of the Relationship

The imperative for tools and proficient personnel in the understanding and design of instrumentation for measuring marine environmental parameters becomes evident, especially in the assessment of climate change impact. (Global Ocean Observing System GOOS) [3]. The specificity of the content presented in Table 3 underscores the necessity for instruction to be imparted by expert professor–researchers in the field. This need is justified through two overarching concepts. The role of research as a fount of knowledge for teaching, and the involvement of students in research projects pertaining to marine environmental technologies [6].

Global competition among universities, as reflected in university rankings, reinforces a singular model of a distinguished university, often distilled to excellence in research [19]. Higher education institutions (HEIs) are undergoing a gradual transformation from entities primarily focused on teaching to research-intensive institutions, possessing substantial but underutilized knowledge resources [20]. Strategies to harness these resources for learning, framed within the context of knowledge management (KM), are examined in [21]. Within this framework, the research–teaching nexus (RTN) enriches learning outcomes [22] by involving students in research activities [23] and concurrently yields professional and organizational advantages. Research skills are not only integral to academic pursuits but also constitute essential professional competencies that students and graduates should possess [24].

It is often debated whether being a proficient researcher correlates with being an effective teacher, whether professors actively engaged in research outperform those who are not, and, more broadly, whether research and teaching activities can synergize. While answers to these questions are crucial for optimizing the allocation of human resources between research and teaching, the existing empirical evidence is limited [25]. Findings indicate that master's students instructed by research-active professors attain higher grades, underscoring that research-based teaching is more captivating than theory-based instruction [26]. The results highlight positive direct relationships between faculty knowledge, self-efficacy, intrinsic interest value, and the promotion of metacognition [27]. Research-active professors are more inclined to integrate research findings into teaching, involve students in research groups, and co-publish with them [19].

Engaging in research enhances the teacher's competence in their subject and keeps them abreast of the latest developments in the discipline. Consequently, research activities positively impact teaching quality; during classroom discussions, researchers can impart their critical thinking and research skills to students [28–32]. However, both research and teaching activities demand a substantial investment of time and effort. The time and effort devoted to research may, in turn, reduce the resources available for teaching. This allocation of time and effort is influenced by the incentive system in the academic field, where the quality of research often carries greater weight than the quality of teaching. Consequently, individuals in academia may prioritize research over teaching, as building an academic career is frequently perceived to be more achievable through research, while teaching is sometimes regarded as a dispensable obligation [19,33,34]. Even though teaching staff at Spanish universities are typically appointed with a primary focus on covering teaching loads rather than research, meaning teaching and research must be balanced, aligning the subject matter in the classroom with research activities allows for the optimization of preparation time, despite potential differences in details and language.

In the context of teaching the Marine Technologies specialization in the Bachelor's Degree in Marine Science and Technologies, it is noteworthy that the instruction is conducted by professors affiliated with the SARTI research group. This leads to teamwork stemming from being part of a research group, where each professor does not confine themselves to their discipline, and there are no closed compartments as the theme is common to all professors. In a collaborative environment, the professors jointly plan and discuss lessons focusing on teaching the subject matter and student learning (Lesson Study, LS) [35,36]. In addition, there is access to specific research equipment, now also for educational use, and the transmission of norms and values of scientific research to students [19]. Building a professional identity is an ongoing task for professors [37,38]. The competencies of Self-Regulated Learning (SRL) underscore the dual role of teachers as both learners and facilitators in promoting metacognitive skills and the SRL of their students [39–41]. The results obtained show a significant relationship between leadership and innovation [42].

#### **4. Tools to Ensure Success in the Transfer of Knowledge in the Bachelor's Degree in Marine Technologies**

Once the content and objectives of the Marine Technologies specialization courses have been defined in Section 2, Section 4 will present the teaching suitability of the SARTI members and their contributions in equipment for carrying out experimental activities. This section is therefore structured into three blocks. First, the most relevant indicators achieved in teaching electronic instrumentation; second, the underwater observatory (OBSEA) as a fundamental infrastructure for teaching; and third, the trajectory in technology transfer and research in the design, development, and implementation of marine technologies.

##### *4.1. Background to the Teaching of Electronic Instrumentation at the Vilanova Campus*

The teaching trajectory for the electronic instrumentation of the SARTI group can be traced back to 1994 at the Vilanova Campus of UPC, when the authors of this work launched a laboratory of instrumentation and control, equipped with ten workstations fit-

ted with data acquisition cards, GPIB instrumentation (General Purpose Interface Bus), and one computer per station with the programs LabVIEW (National Instruments) and HPVEE (Agilent). This infrastructure helped advance the concept of virtual instrumentation [43]. Virtual instrumentation is based on the use of modular software and hardware accessible and controllable from a computer so that the user can create their own instrument for a specific application. The instrument is virtual, it does not exist as such, but performs functions such as measuring, processing, storage, etc. The experience in this field allowed the achievement of a series of results, including the following: *certified instructors* (Agilent Technologies, National Instruments); *the design of GPIB equipment with student involvement* (a research team of four students and three professors was formed to design and build a series of low-cost GPIB instruments for Promax Electrónica, SL [44]); *books on the subject* (four on LabVIEW and two on virtual instrumentation); *European teaching initiatives under the Leonardo da Vinci/Erasmus program* [45]; *student participation in instrumentation and control projects for companies* (KUKA, General Cable, Prysmian, etc.); *undergraduate thesis projects in electronic engineering* (102 projects from 1994–2000); *ongoing training funded by European sources* (with registration number 427, accredited by the Generalitat de Catalunya from 1993–2019, providing 19,752 h of practical training through 64 courses in collaboration with local and regional technology companies, and this initiative significantly contributed to placing students in roles as specialists in advanced instrumentation techniques); *training at company facilities* (a total of 740 h distributed across 28 agreements from 1994 to 2021, covering topics such as distributed sensors, IEEE/ISO standards, control devices, databases, and automation); and *awards for the creation of teaching materials* (UPC 1995 “Virtual Instrumentation for Signal Acquisition, Processing, and Analysis” and UPC 1997 “A Virtual Environment for Experimentation”).

#### 4.2. Creation of a Marine Research Infrastructure

In the preceding section, we delineated some of the activities facilitated by the existence of the Instrumentation and Control Laboratory. These initial steps required reinforcement by identifying a specific area of interest for focused research, a niche that was not addressed by the research endeavors of other national groups and the university itself. The identification of such a niche provides a unique opportunity to collaborate with various research groups across very different fields in electronic engineering, enabling high-quality research. This is reflected, among other things, by the publication of doctoral theses completed exclusively at the Vilanova campus, thereby establishing autonomy from the central UPC services at the Barcelona campus.

The decision to focus on research in the marine environment has been influenced by the location of the Vilanova Campus and by previous collaborations with other research institutions. Vilanova i la Geltrú, the capital of the Garraf comarca, is located 40 km south of Barcelona. It is a city with a population of about 70,000 inhabitants and a strong maritime tradition. The port of Vilanova i la Geltrú is one of the most important ports managed by the Government of Catalonia, both in terms of the fishing fleet and the economic activity generated [46]. The Vilanova Campus is situated in the “Costes del Garraf” area, designated as a Site of Community Importance (SCI), Special Protection Area for Birds (SPA), and part of the Natura 2000 Network. Located within the metropolitan region of Barcelona, it is an ecologically valuable area but is subject to high environmental pressure due to a dense population. On 14 May 2001, a framework collaboration agreement (Associated Unit Tecnoterra) was established with the Spanish National Research Council (CSIC Spain’s state agency for research and development.

These two reasons—location (Port-Natura 2000 Network, etc.) and the science–technology symbiosis (CSIC Associated Unit)—guided the research direction for the SARTI group. Research in technologies applied to the marine sciences intensified with the launch of the underwater observatory. (Expandable Underwater Observatory OBSEA) Table 4.

**Table 4.** A sample of the publications derived from the research projects carried out at the OBSEA observatory.

Research Activity	Publication Reference
Sensors Interoperability	IEEE Journal Oceanic Engineering (DelRio et al. 2018) [47]
Energy Harvesting	IEEE transactions on power electronics (Carandell et al. 2022) [48]
Data Management	IEEE Access (Martinez et al. 2021) [49]
Marine Instrumentation	IEEE Acces (Del Rio et al. 2020) [50]
Underwater Acoustic Telemetry	Measurement (Toma et al. 2018) [51]
Robotics	Journal of marine science and engineering (Falahzadehabarghouee, A et al. 2023) [52]
Behavior of the species	Scientific data (Francescangeli, M et al. 2023) [53]
Video-imaging system	ICES journal of marine science (Aguzzi et al.2020) [54]
Metrology	Measurement (Garcia et al. 2018) [55]

In the context of the ESONET Network of Excellence under the Sixth Framework Program, in the SARTI group, laboratories commenced the design and construction of a sea bed observatory starting in 2007 [56]. Since May 2009, the OBSEA observatory has been operational, situated 2.5 nautical miles offshore from Vilanova’s coast, at a depth of 20 m, and connected to the SARTI laboratories via a hybrid cable combining fiber optic and electrical power [57]. This initiative represents a project developed, manufactured, and deployed by the SARTI research group, rather than commercially purchased equipment. This achievement provides significant knowledge for the teaching of marine technologies.

The OBSEA observatory is a highly flexible equipment that is scalable and adaptable to various configurations, facilitating the integration of diverse sensor types (Tables 5 and 6). Details of the infrastructure can be found in the publication “Obsea: A Decadal Balance for a Cabled Observatory Deployment” [50], Figure 2. It serves as a readily accessible laboratory, fostering collaboration within national and European consortia for testing and implementing new technologies intended for deep-sea deployment. The infrastructure supports continuous sampling, ranging from real-time intervals of seconds to long-term time series, enhancing the understanding of environmental dynamics, ecosystem evolution, natural hazards, etc. The effective management of these data supports informed decision-making in coastal conservation and integrated management.

**Table 5.** Obsea instrumentation list.

Instrument	Measured Parameter(s)	Elevation Depth	Sampling Frequency	Frequency of Data Recovery
Seabird SBE16plusV2	Water temperature, conductivity, depth, sound velocity, and salinity	−20 m	20 s	Real-time
Seabird SBE37SMP	Water temperature, conductivity, depth, sound velocity, and salinity	−20 m	20 s	Real-time
Underwater camera OPT-06	Images	−20 m	10 frames/s	Real-time
Hydrophone Bjorge Naxys	Sound	−20 m	Up to 768 kS/s	Real-time
Nortek AWAC	Water currents, wave height and direction, turbidity, and chlorophyll	−20 m	10 min	Real-time
Nanometrics Broadband sismometer Trillium 120P	Tectonic movement	−20 m	Up to 175 Hz	Real-time

**Table 5.** *Cont.*

Instrument	Measured Parameter(s)	Elevation Depth	Sampling Frequency	Frequency of Data Recovery
Buoy weather station Airmar 150WX	Air temperature, pressure, and wind speed and direction	5 m	30s	Real-time
Mobotix M24 buoy camera	Images	5 m	12 frames per second	Real-time
Land Davis Vantage Pro2 Weather Station	Air temperature, humidity, pressure, wind speed and direction, and rain	14 m	10 min	Real-time
LICOR LI-820 CO <sub>2</sub> Gas Analyzer	CO <sub>2</sub> concentration in air	14 m	30 s	Real-time

**Table 6.** Obsea platform features.

Infrastructure Name	Expandable Seafloor Observatory (OBSEA)
Legal name of operating organization	Universitat Politècnica de Catalunya (UPC)—(SARTI) Fixed point observing system.
Coordinates (details) Mediterranean—Balearic Sea—Catalan Sea—Central Coast—Garraf Coast	<ol style="list-style-type: none"> <li>1. Surface buoy: OBSEA buoy; 41.1820° N 1.7527° E</li> <li>2. Coastal cabled system: Subsea station 1; 41.1819° N 1.7524° E</li> <li>3. Meteorological Station 41.2235° N 1.7363° E</li> </ol>
Description of the system	Fixed point observing system. <ol style="list-style-type: none"> <li>1. Surface buoy equipped with weather station (temperature, pressure, wind, GPS, and compass) and camera.</li> <li>2. Coastal cabled system equipped with CTD, hydrophone, camera, AWAC waves and current meter, and seismometer</li> <li>3. Meteorological station equipped with temperature, humidity, wind, rain, pressure, and CO<sub>2</sub> sensors.</li> </ol>
Web site address	<a href="http://www.obsea.es">http://www.obsea.es</a> (accessed on 24 September 2024)
Additional services/data	The Master CLK supports the IEEE std. 1588 Precision Time Protocol, functioning as a network master clock for synchronization purposes. It interfaces with a GPS for timing reference. Custom C instrument drivers are utilized to generate NMEA-style frames via UDP or TCP on the network. Various services are available in C, JAVA, LabVIEW, PYTHON, PHP, and other languages for data processing and archiving purposes. OGC SOS provides interoperable access to data. Plug’n’play capabilities are available using OGC-PUCK and SensorML.

*4.3. Research and Technology Transfer, Tools for Knowledge Transfer*

In today’s information and knowledge-driven society, it is undeniable that the productivity and competitiveness of companies are closely tied to their innovation capabilities and their adeptness in adopting new technologies [58]. This necessitates public universities, as drivers of regional innovation, to effectively harness, transfer, and commercialize their knowledge. In this section, we will outline the research landscape in our local context (Catalonia). Following that, we will detail the research activities of the SARTI group, many of which are characterized by the involvement of students in the final years of master’s degree programs at the Vilanova Campus.



**Figure 2.** Underwater view of the Obsea observatory and the artificial reefs.

First of all, it is worth mentioning the recognition of the SARTI group by the University. In 2004, the first catalog of research groups was established by the UPC's Governing Council. Since then, the SARTI research group has been included, a multidisciplinary research group composed of investigators from various departments at the Vilanova-UPC campus (mechanical engineering, electronics, mathematics, physics, and chemistry). The activities of SARTI are aligned with the Research Innovation Strategies for Smart Specialization in Catalonia (RIS3CAT), which is Catalonia's response to the European Commission's call for states and regions of the European Union to develop research and innovation strategies for smart specialization tailored to their innovation potential [59]. Within this strategy, Catalonia's R+D+i Units are structured around six lines of action: universities, research centers, large infrastructures, hospital institutions, technology transfer, and networks and research groups recognized by the Government of Catalonia (SGR) [60]. The SARTI group, among these six lines of action, is accredited as a Technology Transfer Center [61] and a member of a network (BlueNetCat) with the goal of creating an interdisciplinary ecosystem for transfer and innovation, thereby enhancing the competitiveness of the Blue Economy in Catalonia [62]. Finally, it is worth mentioning that the OBSEA infrastructure is part of iCIEM (Integrated Coastal Infrastructure for Experimentation and Simulation) [63], a research group recognized by the government, and part of a large infrastructure.

In the line of action of technology transfer, the Innovation Plan 2001–2004 of the Government of Catalonia emphasized increasing awareness in the industrial sector regarding the significance of innovation and advancing the transfer of knowledge from universities to industry. This was achieved through the establishment of the Network of Centers for Technological Innovation Support (XIT). The primary objective of XIT is to stimulate the market for research and development outsourcing and promote the transfer of technology from universities to businesses. In 2001, SARTI was designated as an XIT Center, receiving the TECNIO accreditation [61], which has been constantly renewed every year (there are only 15 TECNIO centers at the UPC). This accreditation has been complemented by several quality certifications and accreditations, including the ISO/IEC 17025 ENAC accreditation for the Metrology Laboratory, crucial for ensuring the quality of electronic instrumentation education. Additionally, SARTI holds ISO 9001:2020 certification issued by Det Norske Veritas, covering electronic instrumentation (Table 7, technology transfer actions).

**Table 7.** In the period 1994–2022, projects, services, and training programs developed by SARTI.

Projects and Services	Agreements Framework	Training	Total Transfer Actions	Industrial Property
873	23	28	924	8

This section concludes with a summary of some significant research activities conducted by the SARTI group. These include the organization of international conferences (11 editions of the Marine Technology Workshop Martech (Figure 3) [64], Mediterranean Oceanographic Instrumentation Campus 1998–2000, Midwest—Circuits and Systems IEEE MWSCAS2006, IMEKO TC 4 Barcelona 2013 [65], IMEKO 2009, Lisbon, etc.). Scientific productivity includes 96 books and book chapters, and 528 journal articles (Table 8). The group also engages in journal evaluations (IEEE, MPDI, Springer Verlag, Elsevier, etc.). Competitive projects from 1994–2022 are listed (Table 9). Agreements with public entities include collaborations with CSIC, the Cartographic and Geological Institute of Catalonia, MeteoCat, and Colls-Miralpeix Costa del Garraf, among others. National university networks include Marinetech [66] and the Spanish Committee for Oceanographic Observations [67], as well as Erasmus exchanges for students and professors, European consortia since 2005 with the European Marine Observation Network [68], and associations with international centers on research projects and student scholarships (2010–2021), including the MBARI Summer Internship [69], Marie Curie postdocs, Jacobs-Germany, Open Geospatial Consortium [70], University of Matanzas Cuba (2001–2004), ISEN-Brest-France, IST-Lisbon-Portugal, etc. The group is a member of public marine parameter databases (OceanExpert [71], EMODnet [72], and EMSO [73]) and publishes an open-access journal designed to highlight the activities of the SARTI research group and other groups working in related thematic areas [74]. Instrumentation Viewpoint (2003–2023, 22 issues, 936 articles ISSN 1697-2562) is one such publication.



**Figure 3.** Cover of the first edition of Instrumentation Viewpoint and the poster of the first edition of the marine technology workshop.

Final-year students in the Marine Sciences and Technologies degree program can publish an article in Instrumentation Viewpoint and/or present work at the Martech conference, both excellent opportunities to engage in the development of marine-applied technologies (see Figure 3).

Finally, this section presents the development of Scientific Tools for the public. Due to climate change, there is a shift in the distribution of marine species, with a decrease

in native species and an increase in invasive species. The data recorded by the measurement equipment installed in OBSEA (Table 5), including a camera, will provide valuable information for studies on the evolution of marine fauna. One of the activities promoted by SARTI is “citizen science”. Involving citizens in monitoring the species, they can use a web application to access images from the underwater camera. Once captured, these images are compared with a database of images previously registered by CSIC-SARTI researchers. Participating citizens can see that their contributions produce tangible results in scientific research [75,76]. In addition to scientific dissemination activities, the design of didactic units for primary schools is carried out, as well as participation in exhibitions such as “The Mediterranean [77]. Our sea like you’ve never seen it before” at Cosmo Caixa (Barcelona) [78]. SARTI research and teaching activities are carried out at the Vilanova campus, far from the UPC’s main headquarters in Barcelona. Since there were no active research groups on the Vilanova campus, it became necessary to find the necessary resources to set up an independent research group and provide it with the necessary infrastructure. This dynamic has led to the acquisition and transmission of entrepreneurial skills, and has achieved a presence in the national and European context with notable scientific production (Table 8) and a significant number of competitive research projects (Table 9). Table 10 shows some ongoing research projects that demonstrate the continuity of activities in the coming years and allow for student participation. Our aim is for this experience and the developed activities to serve as a practical example for students and other academic institutions aspiring to foster an entrepreneurial attitude in their teaching and applied research activities in marine sciences and technologies.

**Table 8.** Scientific productivity of SARTI–UPC from 1994 to 2022 [79].

Journal Article	Presentation Work at Congresses	Book	Book Chapter	Research Reports	PhD’s Thesis	Award or Recognition
540	1108	65	31	114	34	28

**Table 9.** Number of competitive projects.

Time Period	Spanish State	Great Facilities	Generalitat	Other Institutions	European	Total
1994–2023	101	16	33	15	31	196

**Table 10.** Currently active research projects funded through competitive calls on Marine Science and Technologies topics.

Name of the Project	Initial Date	End Date
SunBIO: sustainable and nature inclusive offshore energy with the parallel biodiversity flourishing, protection and monitoring	01/01/2024	31/01/2026
Digi4ECO: Integration of biodiversity monitoring data into the Digital Twin Ocean	01/01/2024	31/12/2027
ANERIS: operAtional seNsing lifE technologies for maRine ecosystemS	01/01/2023	31/12/2026
GEORGE: Next generation multiplatform Ocean observing technologies for research infrastructures	01/01/2023	30/06/2027
Into The Deep: Marine Image Analysis Hub for Citizen	01/11/2022	30/10/2024
Geo-INQUIRE: Geosphere Infrastructures for Questions into Integrated Research	01/10/2022	30/09/2026
eImagine: Imaging data and services for aquatic science	01/09/2022	31/08/2025
SlagReef: 3D slag concrete manufacturing solutions for marine biotopes	01/12/2022	30/11/2024
MINKE: Metrology for Integrated Marine Management and Knowledge-Transfer Network	01/04/2022	31/03/2025
JERICO: Joint European Research Infrastructure of Coastal Observatories: Science, Service, Sustainability	01/02/2020	31/01/2024
PLOME: Long Duration Platform for the Observation of Marine Ecosystems	01/12/2021	30/11/2024
BITER: Joint effort between biology and technology to monitor and recover species and ecosystems impacted by fishing: multiparametric observation platforms	01/09/2021	31/08/2025

### 5. Discussion: Indicators of Teaching Activity in the Mention of Marine Technologies

The previous sections analyzed the need for the Marine Technologies specialization in the Marine Sciences and Technologies degree, and having defined the main skills, generic objectives, and most relevant contents of the various subjects within the Marine Technologies specialization, this section examines the link between teaching and research. It demonstrates the quality of teaching achieved by faculty members of a research group responsible for the entire teaching of the Marine Technologies specialization compared to professors linked to university departments who generally do not work as a team.

Teaching quality can be measured from two perspectives, that of the professor and the student. Student surveys on teaching performance, both regarding faculty and the subjects taught, are a widely used resource in university institutions. Although these surveys have been heavily criticized for being based on students’ perceptions, their enjoyment of the course, and the empathy of the professor rather than characteristics related to teaching quality [80], they are the tool we have and will use in this work. It should be noted that using student evaluations is not recommended when response rates are low or differ significantly between different courses. Since student evaluations cannot be the sole indicator of teaching quality, other measures should be used [81].

The other indicator we will use in this study will be student grades in the analyzed subjects. Here, it is also important to consider the grading tendencies of the professors, which may lean towards either high or low grades [82], a tendency that is related to departmental characteristics and individual professor-specific factors [83]. Additionally, universities may have a tendency to facilitate students passing their courses to improve the university ranking. It is also important to consider that student performance may be influenced by various personal situations unrelated to teaching effectiveness. Taking these considerations into account, we will use both student surveys and student grades as measures of teaching quality [84]. Regarding the format of the surveys conducted by UPC with students, we can say that they are structured with four questions, using a rating scale from one—Strongly Disagree, to five—Strongly Agree.

1. Question 1: The content of the subject has seemed interesting to me.
2. Question 2: In general, I am content with this course.
3. Question 3: The professor presents the content clearly and resolves doubts.
4. Question 4: The professor has helped me learn.

Table 11 presents the average values of the responses to the survey for the subject “Instrumentation and Data Analyses in Marine Sciences” for the academic years 2020–2021, 2021–2022, and 2022–2023 in the Q2 semester. These response results for the four questions are centralized within the teaching departments and are only accessible to the involved professors. The table shows that the results for the professors of “Instrumentation and Data Analyses in Marine Sciences” have better outcomes compared to the department to which the professors are affiliated, the academic center, and the university’s overall degree programs.

**Table 11.** Average survey results for “Instrumentation and Data Analyses in Marine Sciences” for the academic years 2020–2021, 2021–2022, and 2022–2023.

	Instrumentation and Data Analyses in Marine Sciences	Department	Center	UPC
Question 1	4.16	3.72	3.88	3.81
Question 2	4.13	3.42	3.65	3.56
Question 3	4.60	3.95	4.02	4.00
Question 4	4.58	3.89	3.96	3.92

(Note: Values are given on a scale from one to five, where one is “Molt en desacord (Strongly Disagree)” and five is “Molt d’acord (Strongly Agree)”.

The responses for all three academic years have been above four, a value that aligns with the positive reception of the degree in the university’s offerings. The results for

question 4 (“The professor has helped me learn”) are considered relevant by the university and can be consulted at the degree, center, and university levels [85]. Table 12 shows that the best results for question 4 of the degrees taught at the UPC are found in the Marine Sciences and Technologies degree. Table 11 shows that the results for Instrumentation and Data Analyses in Marine Science are even better.

**Table 12.** Answers to question 4 for degrees taught at the UPC for the 2020–21 and 2021–2022 academic years.

Course-Term	Marine Science and Technology	ETSECCPB	UPC
20–21 Q2	4.01	3.92	3.86
21–22 Q2	3.99	3.79	3.94

Regarding student success rates, we observe that the success rate increases with the progression of the degree, especially in the third and fourth years with the teaching of marine technology subjects. Table 13 compiles data on grades from the academic year 2020–2021 Q2 to 2022–2023 Q1, including two subjects from the second semester of the third year and four subjects from the first semester of the fourth year. The pass-to-enrollment ratio for marine technology subjects is 96.92%, compared to the UPC average of 74.2%. The same pattern is observed in the graduation success rates in Table 14; comparing the total number of students who have completed their degree at the UPC and those who have done so at the ETSECCPB, the Marine Sciences and Technologies degree has the best average grade and the shortest duration of studies.

**Table 13.** Four quarters. Academic periods: 2020–2021 Q2, 2021–2022 Q2, and 2022–2023 Q1.

	Institution	Enrolled Students	Passed Students	Success Rate
UPC (University Average)	103.423	76.974	74.2%	5.7
ETSECCPB	4.744	2.358	69.1%	5.2
Marine Science and Technology	1.140	869	75.4%	5.6
Technology subjects	260	252	96.92%	7.3

**Table 14.** Number of graduates (average grade and duration of studies) for UPC, ETSECCPB, and Marine Sciences and Technologies.

Academic Course	ETSECCPB Graduates			Marine Sciences and Technologies			UPC		
	N°	Note	Time	N°	Note	Time	N°	Note	Time
2021–2022	79	7.81	5.44	10	8.5	4	3048	7.02	5.18
2022–2023	89	7.54	5.47	31	7.77	4.39	3157	7	5.2

Other aspects to consider in the quality of education are the internationalization of the degree and the gender ratio among students. In Table 15, a comparison is presented between the internationalization level of the university as a whole and the evolution of the Marine Sciences and Technology degree. It can be observed that, at the university level, the percentage of international students remains constant at 6% over the years. In the Marine Sciences and Technologies degree, despite having only two graduating classes (Table 13), there is a trend of increase from 0% in the 2018–2019 academic year, the first year of the program. The degree attracts students from Germany, Andorra, Mexico, the Netherlands, Peru, Poland, the United Kingdom, Romania, Ukraine, Argentina, Algeria, and China. Table 16 indicates that the presence of women in the Marine Sciences and Technologies degree is significantly higher at 45.36% compared to the overall UPC percentage of 27.24%

for the period 2018–2023. Out of the 55 [86] Bachelor’s degrees at UPC, Marine Sciences and Technology ranks among the top 10 with the highest percentage of women.

**Table 15.** Internationalization of the marine sciences degree.

	Women	%	Men	Internationalization	Internationalization at UPC
2022–2023	105	46.67%	120	5%	6%
2021–2022	89	44.28%	112	3%	6%
2020–2021	76	46.63%	87	1%	6%
2019–2020	46	45.54%	55	3%	6%
2018–2019	21	39.62%	32	0%	6%

**Table 16.** 2018–2013 gender balance.

Undergraduate Students	Women	%	Men	%
UPC (all)	28.937	27.24%	77.281	72.76%
ETSECCPB Degrees	1.351	30.08%	3.141	69.92%
Marine Sciences and Technology Degree	337	45.36%	406	54.64%

Finally, with the registered enrollment data, the successful launch of the degree program in Marine Sciences and Technologies is demonstrated. Table 17 shows the evolution of enrollment in Marine Sciences and Technologies, with the ratio (students in the degree/all degrees in the center) increasing from 7.07% in 2018 to 20.89% in 2023. The number of students in different degrees at ETSECCPB was 1187 in the academic year 2012–2013, decreasing to 741 in the academic year 2017–18. This decline was partially halted by the introduction of the Marine Sciences and Technologies degree with an initial offering of 50 spots in the first academic year 2018–2019 and 60 in the subsequent years.

**Table 17.** Evolution of enrolment in the Bachelor’s Degree in Marine Science and Technology.

Academic Course	ETSECCPB Bachelor’s Degrees	Marine Sciences and Technologies Bachelor’s Degree	%
2018–2019	750	54	7.07%
2019–2020	788	101	12.82%
2020–2021	888	163	18.36%
2021–2022	989	201	20.32%
2022–2023	1077	225	20.89%
2023–2024	1143	217	18.99%

In experimental programs like the Bachelor’s Degree in Marine Sciences and Technologies, part of the activities involve fieldwork at sea. The location of the school in a port city like Vilanova, the availability of scientific equipment, the symbiotic relationship between science and technology with the Marine Sciences Institute, and the infrastructure provided by the SARTI group are essential for carrying out these studies. The high level of student motivation is reflected, for example, in the high success rate of students in Instrumentation and Data Analyses in Marine Sciences, as shown in Table 18. Similarly, in the YouTube video [87] and in surveys, some student comments about studying at the Vilanova Campus highlight the close relationship with the teaching staff. Experiences like “Studying in Vilanova has been a pleasure; I really enjoy the content of the course, which combines theory and practice; you gain knowledge to work in what you love; I have enjoyed the practical work on the boat,” etc., underscore the positive impact of the program.

**Table 18.** Grades for courses where the subject of Instrumentation and Data Analyses in Marine Sciences has been taught.

Academic Course	Students Number	Failed	5–6	7–8	9	10	Pass	7–10
2020–2021 Q2	22	1	8	6	6	1	95.45%	59.09%
2021–2022 Q2	44	0	15	13	14	2	100.00%	65.91%
2022–2023 Q2	37	4	14	9	9	1	89.19%	51.35%

Like any study, this one also has limitations. Some variables are challenging to measure, such as opinions, reasons, and personal perceptions. Other types of data, such as learning outcomes, can be measured in multiple ways in principle. In our case, due to the practical limitations of this study, we chose to collect data from exams and/or control tests (performance rate). Since there are only two cohorts of graduates, and the data recorded on the UPC website may not fully show the results of the 2022–2023 academic year, the study sample may be somewhat limited. This limitation should be considered along with the impact of the COVID epidemic in the 2020–2021 Q2 academic year, the first semester of teaching Instrumentation and Data Analyses in Marine Sciences.

It has been demonstrated that to assess the quality of teaching processes, it is necessary to complement the information from student surveys and grades with data derived from students' personal and contextual variables [26]. These aspects should be a focus of future research, aiming to understand the different factors that influence academic performance [84].

## 6. Conclusions

The introduction of this work explained the problems associated with the sustainable development of the oceans, and the need to have highly qualified personnel with an entrepreneurial profile in order to face the challenges of the oceanic decade and to be able to cover the needs of the Blue Economy [5,6]. By analyzing the academic offerings, particularly the existing university degrees related to marine sciences and technologies at Spanish universities, we were able to identify technological gaps and propose to academic administrations a new degree in Marine Sciences and Technologies with a focus on Marine Technology, specifically in electronic instrumentation [17]. The teaching of this specialization has been developed by members of the SARTI research group. The fact that the professors are linked to the same research group has allowed us to analyze, as a case study, the connection between teaching and research. The results of this case study have been detailed in the previous section. It is evident that the best results in the question "The professor helped me learn" are achieved by the Marine Sciences and Technologies degree compared to all of the degrees offered by UPC (Table 11), and the percentage is even higher for the subject of Instrumentation and Data Analyses in Marine Sciences (Table 12). Additionally, the pass-to-enrollment ratio for Marine Technology subjects is significantly higher than for other UPC degrees (Table 13), and students completing their studies present the highest average grade and the shortest duration of studies (Table 14). Based on these results, we can consider that the teaching–research connection is beneficial, with a high level of student motivation reflected in the high success rate in the subject of Instrumentation and Data Analyses in Marine Sciences (Table 18), as well as the growing interest in the degree, shown by a constant increase in new enrollments (Table 17).

Throughout this work, we have considered that university professors should engage in teaching, research, and technology transfer to the industrial sector. Only by acting on these three axes can we address and solve the new future challenges. If only teaching is carried out, we will have engineers with technical training, but outside the social context [88,89]. Today, society demands that universities increase their knowledge transfer potential. Applied and basic research projects need to be transformed into industrial patents and generate spin-offs. However, this has key actors, which are the professors. Within the

university framework, entrepreneurial activities required of the professors are not always recognized or valued, yet they are crucial, especially considering how the current skills of some (professors) can influence the future skills of others (students). The fact that the teaching of the Mention in Marine Technologies of the Bachelor's degree in Marine Sciences and Technologies is carried out by a research-active group has allowed the integration of creative thinking and the development of differentiated skills from traditional teaching, many of which will be useful for students to obtain qualified employment. It is worth mentioning that years of entrepreneurial experience in knowledge transfer have enabled involving a substantial number of students in the evaluation of real-world problems, thereby fostering creative thinking as a cognitive tool that drives innovation [90]. Consequently, the SARTI group has executed ninety-eight research support contracts, and other students have participated and continue to participate as co-authors in research articles published in conferences and journals [64], especially those organized by the SARTI research group (Figure 3), Martech congress, and Instrumentation Viewpoint [74].

In the teaching–research nexus, many are the activities that the team of professors involved in the technological subjects of the Bachelor's in Marine Sciences and Technologies carries out, and this article has endeavored to outline the trajectory of an entrepreneurial career from its inception. There is no better way to articulate the requirements of knowledge transfer than by illustrating how it has been achieved: establishing laboratories, constructing infrastructure like an observatory, publishing journals, organizing scientific congresses on marine topics, generating databases of environmental marine parameters, developing marketing plans, obtaining ISO quality accreditation, etc. This entrepreneurial journey has provided valuable insights into the desired attributes of academic personnel, including perseverance, a goal-oriented attitude, opportunity identification skills, motivation, and others [88,90].

The case study presented here not only provides students with knowledge and skills in various subjects related to marine technologies (Table 2) but also offers specific data for reflection, analysis, and the discussion of possible solutions to a given problem. It does not limit itself to providing solutions to the student but allows for their generation. By guiding the student to generate alternative solutions, it promotes creative ability and innovation, and serves as a direct relationship between theory and applied practice [90,91]. In this work, the results and indicators of teaching activities in the Marine Technologies specialization support the research–teaching nexus in electronic instrumentation, demonstrating that it is an effective tool for enhancing learning and knowledge in marine sciences and technologies.

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