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Comprehensive Evaluation of Naval Architecture and Marine Engineering Curricula in Relation to Sustainable Development Goals and IMO Agenda Topics

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Abstract

The contribution of engineering education is quite significant in achieving the Sustainable Development Goals (SDGs) set by the United Nations, which are planned to be accomplished by 2030. To this end, the evaluation of the engineering curriculum regarding SDGs provides an insightful resource. Determining the alignment of the engineering education with the SDGs involves examining the curricula of institutions that have international engineering accreditation. Naval Architecture and Marine Engineering is inherently a global engineering field, addressing contemporary issues such as sustainability, advanced materials, automation, and safety. It proposes innovative solutions to evolving challenges in maritime transport, offshore energy, and marine environmental protection. Analyzing the relationship between the curriculum and the SDGs, identifying the challenges in aligning the curriculum with these goals, and gathering information to promote engineering education towards achieving the SDGs are all essential aspects of this process. In this study, two Naval Architecture and Marine Engineering curricula, which have ABET accreditation since 2009 and MÜDEK accreditation since 2012, are evaluated with regard to the SDGs. The study presents and discusses the strong SDG 4-7-8-9-12 and weak SDG 1-2-3-13-14-15 areas of the curricula and promotes Naval Architecture and Marine Engineering education for sustainable development.

Keywords: Education for sustainable development, naval architecture and marine engineering curriculum, sustainable development goals, engineering education

1. Introduction

United Nations (UN) adopted 17 Sustainable Development Goals (SDGs) in 2015 as 2030 Agenda for Sustainable Development. The Agenda mainly involves action plans about people, planet and prosperity considering the harmony between the economic, social and environmental aspects with 17 SDGs and their 169 targets. The three fundamental components, environmental protection, economic growth and social equity underpin the sustainable development, seen in Figure 1. The notion of SDGs aims to maintain the main theme of fulfilling contemporary requirements while ensuring that future generations retain the capacity to fulfil their own needs [1]. Furthermore, addressing these issues with transformative steps is crucial for progressive solutions.

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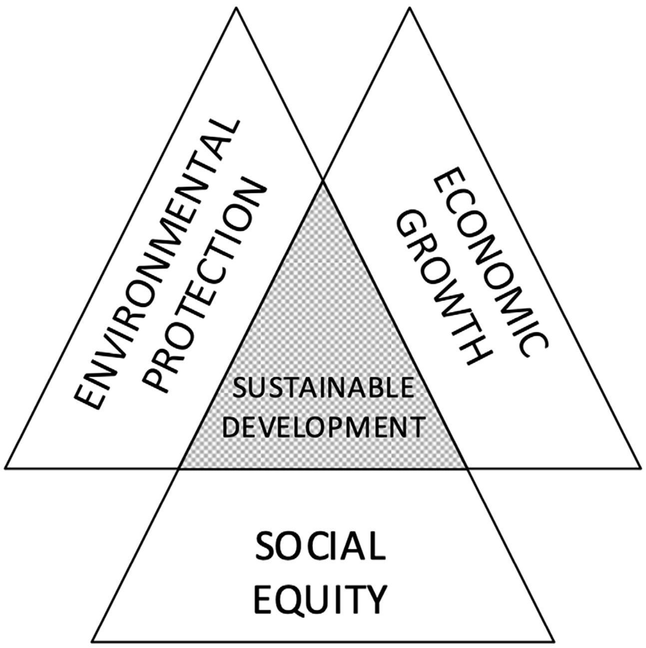

Figure 1. Three fundamental tenets of sustainable development.

UN encourage all member states to expeditiously devise and implement national strategies to ensure the comprehensive execution of this Agenda [2].

Since the concept of sustainable development was first introduced, education has consistently played a key role in supporting the successful realization of its goals [3]. It was also a vital component in the Millennium Development Goals (MDGs), implemented from 2000 to 2015 and later superseded by the SDGs.

The concept of education for sustainable development is an essential pathway to achieving sustainable development, provided that quality education is delivered to transform society by improving the knowledge, skills, values, and behaviors needed for sustainability [4].

Achieving the SDGs in a sustainable manner requires the integration of sustainability principles into all development activities, with a particular focus on higher education (HE). By adopting the SDGs not only in daily life but also the educational framework, and taking into account their long-term impacts, the progress towards these objectives can be created more meaningful and sustainable. The educational goal of the SDGs, as SDG4, largely focuses on the elementary education and literacy fields, and enhancing the notion towards the university level will improve the other SDGs implementation [5]. Given that sustainability is not adequately embedded in the curricula of HE institutions, it poses a significant challenge to the goal of achieving sustainable development [6]. Therefore, the universities are the essential partners in the fulfilment of the 2030 Agenda.

On the other hand, engineers play a crucial role in achieving the UN's SDGs for 2030. Engineering proposes solutions to meet current problems and contribute to economic development by utilizing mathematics, natural sciences, engineering knowledge, and technology. To minimize potential adverse outcomes of these solutions, it must prioritize ethics, economic viability, environmental sustainability, health and safety, and risk management. There is a significant relevancy between the engineering graduate attributes (GAs) and SDGs. In this regard, universities are responsible for fostering an engineering community that is more aware of people, the environment, and equality.

In the 21st-century business environment, engineers are expected not only to offer solutions to current issues using their professional knowledge but also to demonstrate skills that, while different from the disciplinary expertise, contribute to their business. These abilities, attitudes, and understandings, known as GAs, are acquired during students' time at educational institutions.

In professional life, engineers' awareness of their responsibilities develops in line with the skills acquired in basic engineering education. Therefore, receiving education from an accredited education system in the engineering education is quite important. The primary goal of engineering education is to equip engineering candidates not only with engineering capabilities but also competencies that understand and respond to the requirements of the era. In support of this perspective, it can be observed in the report by International Engineering Alliance (IEA) [7] states the World Federation of Engineering Organizations-WFEO-IEA working group established by UNESCO [8] has made improvements under the title "Engineer and the World" to ensure that the GAs and professional competencies (PCs) resulting from engineering education outcomes can contribute to the goals aimed at in the UN SDGs.

As the world moves towards economically, socially and environmentally responsible practices, naval architects play a crucial role in designing eco&human friendly ships and offshore structures. 90% of the products are carried with marine transportation [9]. Education in naval architecture and marine engineering focuses on sustainable design principles, alternative fuels, and reducing emissions, ensuring that future engineers can contribute to a more sustainable maritime industry. Additionally, to protect the lives of crew members and passengers on board the education also comprises the safety standards and risk management. The maritime industry is inherently global, requiring collaboration across countries and cultures so as to understand diverse market needs, and adapt to different regulatory environments. Furthermore, the maritime sector faces contemporary challenges such as climate change, maritime security, and the need for innovative marine energy solutions. By addressing these areas, naval architecture and marine engineering education ensures that graduates are well-equipped to meet the demands of the modern maritime industry and contribute to its sustainable and innovative future.

In the study carried out in World Maritime University [3] about Maritime Education and Training (MET) with the perspective of sustainable development it is emphasized that the foundation for the successful implementation of the sustainable development strategy lies in education, and it was suggested that the MET curriculum should be analyzed in this perspective and that courses to be introduced. The study focuses on the education of future maritime professionals to support sustainable practices, ensuring the industry meets environmental, economic, and social challenges. In another study carried out in Istanbul Technical University [10] the Marine Engineering curriculum have been analyzed so as to determine the relevancy between curriculum and SGSs and strong and weak sides of the curriculum considering 17 SDGs of UN. It is found that there is a need a modernization to achieve sustainable development-based curriculum. In another study, considering MET [4] found out that the education evolving to have a more academic perspective, which helps incorporate SDGs into education, and these educational institutions are becoming more inclined to integrate SDGs into their curricula. There are very limited studies with maritime education strongly based on marine engineering and not existing study about naval architecture and marine engineering to the best of author's knowledge. On the other hand, there are some investigations about SDG integration into universities curriculum as architecture education or nursing [11,12]. It is an anticipated result for different university curricula to prioritize different SDGs; for instance, while SDG 11 (Sustainable Cities and Communities) stands out as the most adapted SDG for the architecture curriculum [11], nursing curriculum prioritizes SDG 3 (Good Health and Well-being) together with SDG 16 (Peace and Justice Strong Intuitions) [12]. Additionally, there are studies that broadly examine the SDG tendencies of HE institutions. The study about universities efforts on integrating SDGs demonstrated that SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), SDG 5 (Gender Equality), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), and SDG 16 (Peace, Justice and Strong Institutions) take precedence [13]. Which seems the areas which the social and economic dimensions are prioritized in [14]. One of the major obstacles to integrating the SDGs into the curriculum is the limited support provided by top management and the reliance on academic staff development for the integration workload [15]. Therefore, conducting an analysis of the existing curriculum is crucial to ensure that valuable efforts are allocated in the most efficient manner for successful integration of SDGs into the curriculum.

In the context of sustainability, understanding the expectations that can be gained from the naval architecture and marine engineering education requires first analyzing the current state of curriculum within the framework of the SDGs, in order to progressive improve and design. Additionally, technological advancements and industrial requirements are parameters that guide the education system.

The main aim of this study is to determine to what extent the naval architecture and marine engineering curriculum includes SDGs. Further motivation is to identify the areas for improvement to increase scope of curriculum regarding SDGs. As an engineering program, it is crucial to determine to what extend the GAs developed by naval architecture and marine engineering students will contribute themselves regarding SDGs. Separately, the results are also expected to contribute to the establishment of quantitative targets for IMO's strategic direction performance indicators that were not clearly defined [16] for activities contributing to the SDGs by IMO.

It must be mentioned that, although the agenda, which is fundamentally focused on the 2030 SDGs, pertains more to the governmental level and was not created for implementation in HE institutions, it is essential for engineering programs to adopt and incorporate this concept and its goals, especially when seeking accreditation from a signatory agency of the Washington Accord [14] which is Represented by Association for Evaluation and Accreditation of Engineering Programs (MÜDEK) in Türkiye. The "Accords" are Mutual Recognition Agreements (MRA) that accredit academic programs and ensure equivalent program outcomes, standards and processes in a certain extent. In the field of engineering science, there are two widely recognized accredited programs: ABET and the Washington Accord. To the best of authors knowledge, the study is antecedent study that analyses the two accredited (ABET and MÜDEK) [17,18]-naval architecture and marine engineering curriculum of a university from the perspective of SDGs.

The curricula used in the study is designed considering ABET and MÜDEK requirements that is a body in IEA. The IEA has made some revisions in recent years to emphasize the contribution of PCs and GAs of engineering education which are already related to SGS, to the SDGs within engineering education. The study evaluates the existing accredited curricula through five main steps, which are detailed in the next section as follows: assessing the connection between the engineering field and the SDGs through a review of relevant literature, systematically evaluating the alignment of both curricula with the IEA's WK topics, mapping each course to the corresponding knowledge and attitude domains, mapping courses to the SDGs, evaluating the curricula in relation to IMO topics, and conducting an overall analysis.

2. Materials and Methods

2.1. The Methodology Outline

This study provides a comprehensive assessment of the undergraduate curricula in Naval Architecture and Marine Engineering at Istanbul Technical University (ITU) and Yıldız Technical University (YTU), considering the UN SDGs, the International Maritime Organization (IMO) agenda topics and the engineering education output perspective. The methodology involves five main steps. Each research step is presented in the flowchart that outlines the procedure in Figure 2.

The first section, Connecting UN SGDs and Naval Architecture, explores the connection between each SDG and the field of Naval Architecture and Marine Engineering, utilizing Carpenter's framework as a reference [19] The second section, Evaluation Curriculum Courses, systematically assesses the alignment of the ITU and YTU curricula with the IEA's WK topics, mapping each course to the relevant knowledge and attitude domains. In Mapping Courses to SDGs, the study examines the extent to which the curricula at ITU and YTU align with the SDGs, highlighting their integration of sustainability principles. The section Assessing IMO Topics further examines the curricula by evaluating the alignment between course content and critical IMO topics, thus determining their adequacy in meeting maritime industry requirements. Finally, in Overall Analysis and Curriculum Recommendations, the study synthesizes the findings, identifying both the strengths and areas for improvement in the ITU and YTU curricula, and offering strategic recommendations for future curriculum enhancements.

2.2. Understanding of SDGs and Connecting with Naval Architecture and Marine Engineering Curriculum

Understanding of the SDGs and their sub targets together with keywords is a crucial step to begin. Table 1 comprises the SDGs and corresponding keywords. SDG1, with the given keywords, encompasses activities aimed at encouraging investments to achieve the goal of reducing humanity's susceptibility to poverty, or contributing to the development of incentive policies. The achieving food security as in the SDG 2 aims to eliminate hunger and achieve food security by 2030 through improved nutrition and sustainable agriculture. It prioritizes access to safe and sufficient food for all. The goal also seeks to boost the productivity of small-scale farmers, protect agricultural biodiversity, and stabilize food markets through enhanced international cooperation and investment. SDG3 covers the well-being and good health and aims to provide universal health coverage and strengthen countries' capacities to manage health risks. SDG 4 seeks to provide inclusive, equitable quality education for all, enhance skills and literacy, promote sustainable development, improve education facilities, expand scholarships for developing countries, and increase the number of qualified teachers. Another complementary SDG for the goal 4 is gender equality as the SDG 5 focuses on achieving gender equality and empowering women and girls by eliminating discrimination, violence, and harmful practices, ensuring equal opportunities and rights. SDG 6, considering ecology, environment and disaster keywords aims to ensure universal access to clean water and sanitation, improve quality, and efficiency in water use by 2030. Additionally, focuses on protecting water ecosystems and improving local participation in water management. SGD 7, comprises clean energy generation, affordable and sustainable energy sources. SDG 8 aims to make economic growth sustainable and inclusive, ensure full utilization of the workforce, and increase quality job opportunities. In order to create increased employment opportunities, as the aim of SDG 8, SDG 9 aims to promote robust economic foundation through infrastructure development and industrial growth, which

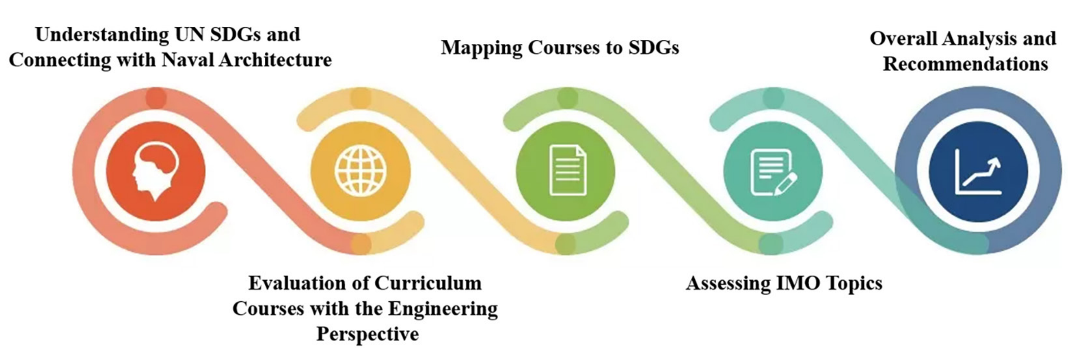

Figure 2. The methodology overview.

Table 1. UN sustainable development goals.

SDG no	SDGs	Keywords
SDG 1	No poverty	Economy, social security, disasters
SDG 2	Zero hunger	Social security, disasters
SDG 3	Good health and well-being	Safety, physical education, health, disaster
SDG 4	Quality education	Practical skill, manual skill, language skill, academic skill
SDG 5	Gender equality	Rules, regulations, law, ethics
SDG 6	Clean water and sanitation	Water, sea, sanitation, ecology, environment, disasters
SDG 7	Affordable and clean energy	Energy, energy generation, energy efficiency
SDG 8	Decent work and economic growth	Ethics, safety, advising, rules, regulations, law, economy, finance, human resource
SDG 9	Industry, innovation and infrastructure	Industry, innovation, infrastructure
SDG 10	Reduced inequalities	Reduced inequalities
SDG 11	Sustainable cities and communities	Law, environment, society, safety, quality
SDG 12	Responsible consumption and production	Energy efficiency, consumption theory, design
SDG 13	Climate action	Environment, disasters, innovative technologies, clean energy
SDG 14	Life below water	Disasters, rules, regulations, environment, ecology
SDG 15	Life on land	Environment, disasters
SDG 16	Peace, justice and strong institutions	Advising, rules, regulations, law, economy, ethics, disasters
SDG 17	Partnerships for the goals	Advising

supports and drives overall economic progress. Goal 10 aims to reduce inequality within and among countries through income growth, social inclusion, and less discrimination. Supporting the reduction of inequalities within countries and ensuring inclusive urbanization of human settlements are also key aspects of SDG 11. Additionally, SDG 11 aims to make habitats safe and sustainable. SDG 12 encompasses the sustainable management of natural resources, the efficient use of these resources, and the reduction of consumption, while also promoting practices in this domain. Sustainable consumption and production models undoubtedly contribute to slow down climate change. Climate action is addressed under SDG 13 as set forth by the UN. This goal encompasses educating, encouraging, and planning for individuals in this field. While SDG 14 covers the sustainable management and protection of marine and coastal ecosystems, as well as the regulation of fishing activities, SDG 15 addresses preventing the degradation of terrestrial ecosystems and improving ecosystem and biodiversity. Institutional reliability addressed by SDG16 is a necessary element for monitoring the mechanisms of the SDGs and implementing supportive policies and besides SDG 17 addresses global partnership to achieve the all SDGs.

In the last part of step 1 the relevance of the Naval Architecture and Marine Engineering field to the UN SDGs is addressed. The relevance is assessed using four different levels: "directly", "partially/directly", "partially", and "non-directly". Table 2 presents the relevance level of each UN SDG in relation to the field of Naval Architecture and Marine Engineering. It has been determined that SDG 3, 4, 5, 6, 7, 8, 12, 13, 14, 16, 17 are directly relevant UN SDGs in relation to the field of Naval Architecture and Marine Engineering. SDG 3 (Good Health and Well-being) is directly relevant to Naval Architecture and Marine Engineering due to its focus on healthcare for seafarers [20] and reducing ship-related pollution [21], with the IMO's role in mitigating health impacts from marine pollution [22] further reinforcing this connection. SDG 4 (Quality Education) is relevant to Naval Architecture and Marine Engineering due to its emphasis on access to quality technical education, which is vital for a skilled workforce, particularly in training for AI and Robotics [23]. The maritime industry is inherently a global sector, and the qualified engineers trained for this global sector are educated in qualified maritime faculties. SDG 5 (Gender Equality) is directly relevant to Naval Architecture due to its focus on eliminating discrimination and increasing women's leadership roles, where the sector has low female representation [24,25]. SDG 7 (Affordable and clean energy) is directly relevant to Naval Architecture as it promotes the use of sustainable energy sources, such as renewable fuels and port electrification, as well as offshore energy generation technologies like wind and tidal power [25]. SDG 8 (Decent work and economic growth) is directly relevant to Naval Architecture due to its emphasis on protecting labor rights and ensuring safe working conditions, especially in ports where many jobs involve low-skilled manual labor, often under

Table 2. SDGs and their relevancy with Naval Architecture and Marine Engineering.

SDG no	SDGs	Description [8]	Relevancy [19]
1	No poverty	End poverty in all its forms everywhere	Partially/Directly
2	Zero hunger	End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Partially
3	Good health and well-being	Ensure healthy lives and promote well-being for all at all ages	Directly
4	Quality education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	Directly
5	Gender equality	Achieve gender equality and empower all woman and girls	Directly
6	Clean water and sanitation	Ensure availability and sustainable management of water and sanitation for all	Partially/Directly
7	Affordable and clean energy	Ensure access to affordable, reliable, sustainable and modern energy for all	Directly
8	Decent work and economic growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Directly
9	Industry, innovation and infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Directly
10	Reduced inequalities	Reduce inequality within and among countries	Non
11	Sustainable cities and communities	Make cities and human settlements inclusive, safe, resilient and sustainable	Partially/Directly
12	Responsible consumption and production	Ensure sustainable consumption and production patterns	Directly
13	Climate action	Take urgent action to combat climate change and its impacts	Directly
14	Life below water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development	Directly
15	Life on land	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Partially
16	Peace, justice and strong institutions	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	Directly
17	Partnerships for the goals	Strengthen the means of implementation and revitalize the global partnership for sustainable development	Directly

unsafe conditions [26]. The need for improved labor rights and secure environments, particularly for migrant and low-wage workers, highlights the importance of this SDG in the Naval Architecture sector. SDG 9 (Industry, Innovation, and Infrastructure) is directly relevant to the Naval Architecture sector as it focuses on investments in infrastructure such as transport, energy, and communication technologies to achieve sustainable development and empower communities [25]. SDG 12 (Responsible Consumption and Production) is directly relevant to the Naval Architecture sector as it promotes sustainable practices across the lifecycle of production and consumption, including the adoption of energy-efficient and environmentally sound technologies in shipping and port operations, which is crucial given that 90% of global trade is transported by sea [9,27,28]. SDG 13 (Climate action) is directly relevant to shipbuilding because the sector plays a crucial role in reducing global carbon emissions through the development of energy-efficient and low-emission vessels, thereby combating climate change [25]. SDG 14 (Life below water) is directly relevant to naval architecture because it emphasizes the conservation of oceans and sustainable use of marine resources, which are critical for designing ships that minimize environmental impact [25]. SDG 16 (Peace, justice and strong institutions) is directly relevant to shipbuilding because it involves ensuring ethical practices, legal compliance, and strong institutions in the maritime industry, which are essential for maintaining peace, justice, and security in global trade and ocean governance. SDG 17 (Partnerships for the goals) known as Partnership for the goals, is relevant to naval architecture because it emphasizes the need for global partnerships that support the exchange of knowledge, technology, and resources, which are essential for advancing sustainable practices and innovations in shipbuilding [25]. It has been identified that SDGs 1, 6, and 11 are partially/directly relevant, SDGs 2 and 15 are partially relevant, and SDG 10 is non-directly relevant to the field of Naval Architecture and Marine Engineering.

3. The Findings of Mapping the Courses and Discussions

3.1. Evaluation of the Curriculum with the Engineering Perspective

This section provides a detailed evaluation of the curricula for the Naval Architecture and Marine Engineering departments at ITU and YTU. Table 3 presents the courses offered in the ITU and YTU curricula on a semester basis. The curricula provided for both universities are the most recent ones, implemented in the year 2024.

The ITU and YTU curricula have been assessed from various perspectives based on the IEA's Knowledge and Attitude Profiles (WKs) to provide a more comprehensive understanding of their characteristics, as shown in Tables 4 and 5. The WKs, or Knowledge and Attitude Profiles, are defined by the IEA as a set of comprehensive criteria that reflect the essential knowledge, skills, and professional attitudes expected of engineering graduates [7]. Each WK represents a specific domain of expertise that is crucial for the effective practice of engineering. These include a systematic understanding of natural and social sciences (WK1), proficiency in mathematics and computational methods (WK2), core engineering fundamentals (WK3), specialized engineering knowledge (WK4), and considerations for sustainable and efficient resource use (WK5). Additionally, they encompass practical engineering skills (WK6), the role of engineering in society (WK7), engagement with current research (WK8), and adherence to ethical standards and inclusive practices (WK9).

Evaluating the first-year courses of the ITU and YTU curricula reveals that the ITU curriculum is focused on natural and social sciences (WK1), whereas the YTU curriculum is heavily centered on mathematics and computational methods (WK2). The ITU curriculum consists of 12% WK1-based courses and 10% WK2-based courses, while the YTU curriculum comprises 14% WK2-based courses and 6% WK1-based courses. In terms of the second-year courses, both universities have a curriculum that predominantly composed of core engineering fundamentals (WK3) courses. In the ITU curriculum, WK3-based courses distributed over the first two years constitute 16% of the all curriculum, while in the YTU curriculum, WK3-based courses covering the first three years represent 18% of the all curriculum. In the third year of study, both curricula are primarily composed

Table 3. Naval architecture and marine engineering curriculum of ITU and YTU.

Istanbul Technical University	Yıldız Technical University
1st Semester	
-Physics I	-Physics I
-Physics I Laboratory	-Int. to Naval Architecture and Marine Eng.
-Int. to Naval Arch. and Marine Eng. and Ethics	-Descriptive Geometry and Technical Geometry
-General Chemistry I	-General Chemistry
-General Chemistry I Laboratory	-Mathematics I
-Mathematics I	-Advanced English I
-English for Academic Purposes	
2nd Semester	
-Physics II	-Physics II
-Physics II Laboratory	-Ship Geometry
-Ship Geometry	-Basic Computer Science
-Int. to Programming Language (PYTHON)	-Mathematics II
-Mathematics II	-Linear Algebra
-Basics of Academic Writing	-Advanced English II
-Entrepreneurship and Career Advising	-Mechanical Workshop
	-Statistics and Probability
3rd Semester	
-Numerical Methods	-Numerical Methods
-Engineering Mathematics	-Differential Equations
-Dynamics	-Mechanics
-Materials and Manufacturing Processes	-Material and Ship Building Materials
-Strength of Materials I	-Computer Aided Design
	-Occupational Health and Safety
	-Technical Thermodynamics I
	-Turkish Language 1
4th Semester	
-Fluid Mechanics	-Fluid Mechanics
-Strength of Materials II	-Strength of Materials
-Thermodynamics	-Technical Thermodynamics II
-Essentials of Research Paper Writing	-Research Project
-Probability and Statistics	-Elective Internship 1
-Technical Elective Course	-Manufacturing Processes
	-Ship Design
	-Turkish language 2
5th Semester	

Table 3. Continued

Istanbul Technical University	Yıldız Technical University
-Marine Engines	-Ship Machinery I
-Ship Theory	-Ship Structural Elements
-Ship Construction	-Machine Elements
-Ship Hydrodynamics (Resistance)	-Heat Transfer
-Maritime and Labor Law	-Ship Hydrostatics and Stability
-Non-Technical Elective Course	-Princp. of Atatürk & Hist. of Modern Türkiye 2
	-Technical Elective Course (x2)
6th Semester	
-Marine Auxiliary Machinery	-Ship Machinery II
-Ship Hydrodynamics (Propulsion)	-Ship Resistance and Propulsion
-Strength of Ships	-Ship Movements
-Ship Design	-Ship Theory
-Electrical Systems in Ships	-Princp. of Atatürk & Hist. of Modern Türkiye 2
-Work Safety & Health Training in Shipbuilding Industry	-Elective Internship 2
-Turkish I	-Technical Elective Course (x^2)
	-Non-Technical Elective Course
7th Semester	
-History of Turkish Revolution I	-Marine Auxiliary Engines
-Naval Architecture & Marine Eng. Design I	-Naval Architecture and Marine Eng. Lab
-Ship Motions and Maneuvering	-Ship Strength
-Methods of Ship Production	-Electrotechnique and Ship Electricity
-Shipping Economics	-Operation and Maintenance of Marine Machinery
-Ship Vibration	-Technical Elective Course (x4)
-Technical Elective Course (x2)	
8th Semester	
-Shipyard Organization	-Shipyard Management and Organization
-History of Turkish Revolution II	-Graduation Thesis
-Naval Architecture & Marine Eng. Design II	-Technical Elective Course (x6)
-Turkish II	
-Computational Fluid Mechanics	
-Technical Elective Course (x2)	

of courses based on engineering knowledge (WK4). These WK4-based courses are supported by sustainable and efficient resource use (WK5) and practical engineering skills (WK6)-based courses. WK4-based courses constitute 29% of the ITU curriculum and 27% of the YTU curriculum. WK5-based courses account for 18% of the ITU curriculum and 16% of the YTU curriculum. In the fourth year, the ITU curriculum is evenly distributed among engineering knowledge (WK4), practical engineering skills (WK6), and engineering in society (WK7)-based courses. For YTU, the curriculum is balanced between WK4 and WK6-based courses. WK6-based courses and WK7-based courses each constitute 18% of both curricula. Research literature (WK8) and ethical standards and inclusive practices (WK9) courses constitute comparatively smaller parts of both curricula.

3.2. Evaluation of the Curriculum with the SDGs

After the understanding of SDGs with a comprehensive approach, as a first step, the curriculum content and SDGs relevancy are to be determined for the study. In order to mapping curriculum courses to the SGDs, firstly the process contains the analyzing the weekly course plan of the all courses in the curricula. The matching the content of the SDGs with the content of naval architecture and marine engineering curriculum is the main body of the study which is carried out meticulously with an annual based approach. The relevancy analysis of the course content with SDGs is determined using the keywords of the SDGs together with their aims and through the studies carried out in literature [9,20-28] on respective areas. The courses may include in their contents one or more SDGs. Therefore, a course name can be represented in multi SDGs in each curriculum analysis. In the evaluation of ITU and YTU curricula, the lecture breakdown structures within the scope of SDG are indicated in Tables 6 and 7.

As seen in the tables, both of the universities' curricula significantly align. There are some differences in the diversity of courses, and what extend differences in the curriculum will affect the SDG evaluation will be presented in the next section. Both curricula include technical and non-technical elective courses. It is expected that these courses will contribute to each SDG, assuming they will be chosen by students from the university's elective lesson pool according to their preferences. It must be emphasized that technical elective courses contribute to all SDGs and will not be specifically mentioned within this statement. To begin with shipping economics have a contribution to SDG 1 in curriculum of ITU. The lectures in YTU; Occupational Health and Safety, Naval Architecture and Marine Eng. Lab contributes to SDG 3 on the other hand, Work Safety & Health Training in Shipbuilding Industry is identified as a supportive lecture at ITU curriculum for this SDG. SDG 4, namely quality education, that is compared to other SDGs, supported by many courses as; Physics I Laboratory, General Chemistry Laboratory, English for Academic Purposes,

Table 4. ITU curriculum breakdown structure regarding to engineering knowledges.

WKs	ITU- Naval Architecture and Marine Engineering Courses
WK1- Natural sciences and awareness of relevant social sciences	Physics I, Physics I Laboratory, General Chemistry, General Chemistry Laboratory, Physics II, Physics II Laboratory
WK2- Mathematics & computing	Mathematics I, Int. to Programming Language (PYTHON), Mathematics II, Numerical Methods, Probability and Statistics
WK3- Engineering fundamentals	Int. to Naval Arch. and Marine Eng. and Ethics, Engineering Mathematics, Dynamics, Materials and Manufacturing Processes, Strength of Materials I, Fluid Mechanics, Strength of Materials II, Thermodynamics
WK4- Engineering specialist knowledge	Marine Engines, Ship Theory, Ship Construction, Ship Resistance, Marine Auxiliary Machinery, Ship Propulsion, Strength of Ships, Ship Design, Electrical Systems in Ships, Ship Motions and Maneuvering, Methods of Ship Production, Ship Vibration, Shipyard Organization, Technical Elective Course
WK5- Engineering design and operations	Ship Theory, Ship Construction, Ship Resistance, Ship Propulsion, Strength of Ships, Ship Design, Naval Architecture & Marine Eng. Design I, Naval Architecture & Marine Eng. Design II, Computational Fluid Mechanics
WK6- Engineering practice	Physics I Laboratory, General Chemistry Laboratory, Physics II Laboratory, Ship Geometry, Naval Architecture & Marine Eng. Design I, Methods of Ship Production, Shipyard Organization, Naval Architecture & Marine Eng. Design II, Computational Fluid Mechanics
WK7- Engineering in Society	Entrepreneurship and Career Advising, Maritime and Labor Law, Nontechnical Elective Course, Work Safety & Health Training in Shipbuilding Industry, Turkish I, History of Turkish Revolution I, Shipping Economics, History of Turkish Revolution II, Turkish II
WK8- Research literature	English for Academic Purposes, Basics of Academic Writing, Essentials of Research Paper Writing
WK9- Ethics, inclusive behaviour and conduct	Int. to Naval Arch. and Marine Eng. and Ethics, Maritime and Labor Law, Work Safety & Health Training in Shipbuilding Industry

Table 5. YTU curriculum breakdown structure regarding to engineering knowledges.

WKs	YTU- Naval Architecture and Marine Engineering Courses
WK1- Natural sciences and awareness of relevant social sciences	Physics I, General Chemistry, Physics II
WK2- Mathematics & computing	Mathematics I, Physics II, Basic Computer Science, Mathematics II, Linear Algebra, Statistics and Probability, Numerical Methods
WK3- Engineering fundamentals	Int. to Naval Architecture and Marine Eng., Differential Equations, Mechanics, Material and Ship Building Materials, Technical Thermodynamics I, Fluid Mechanics, Strength of Materials, Technical Thermodynamics II, Heat Transfer
WK4- Engineering specialist knowledge	Ship Design, Ship Machinery I, Ship Structural Elements, Machine Elements, Ship Hydrostatics and Stability, Ship Machinery II, Ship Resistance and Propulsion, Ship Movements, Ship Theory, Marine Auxiliary Engines, Ship Strength, Electrotechnique and Ship Electricity, Shipyard Management and Organization, Technical Elective Course
WK5- Engineering design and operations	Computer Aided Design, Ship Design, Ship Hydrostatics and Stability, Ship Resistance and Propulsion, Ship Theory, Ship Strength, Operation and Maintenance of Marine Machinery, Graduation Thesis
WK6- Engineering practice	Descriptive Geometry and Technical Geometry, Ship Geometry, Mechanical Workshop, Elective Internship I, Elective Internship II, Naval Architecture and Marine Eng. Lab, Operation and Maintenance of Marine Machinery, Shipyard Management and Organization, Graduation Thesis
WK7- Engineering in Society	Advanced English I, Advanced English II, Occupational Health and Safety, Turkish Language I, Manufacturing Processes, Turkish language II, Princp. of Atatürk & Hist. of Modern Türkiye I, Princp. of Atatürk & Hist. of Modern Türkiye II, Nontechnical Elective Course
WK8- Research literature	Research Project
WK9- Ethics, inclusive behavior and conduct	Int. to Naval Architecture and Marine Eng., Occupational Health and Safety

Table 6. The course breakdown structure of ITU regarding SDGs.

SDGs	ITU- Naval Architecture and Marine Engineering Courses
SDG 1	Shipping Economics, Technical Elective Course
SDG 2	Technical Elective Course
SDG 3	Technical Elective Course, Work Safety & Health Training in Shipbuilding Industry
SDG 4	Physics I Laboratory, General Chemistry Laboratory, English for Academic Purposes, Physics II Laboratory, Ship Geometry, Int. to Programming Language, Basics of Academic Writing, Entrepreneurship and Career Advising, Dynamics, Essentials of Research Paper Writing, Ship Theory, Ship Construction, Strength of Ships, Ship Design, Work Safety & Health Training in Shipbuilding Industry, Naval Architecture & Marine Eng. Design I, Naval Architecture & Marine Eng. Design II, Computational Fluid Mechanics, Elective Internship, Technical Elective Course
SDG 5	Entrepreneurship and Career Advising, Work Safety & Health Training in Shipbuilding Industry, Technical Elective Course
SDG 6	Marine Auxiliary Machinery, Technical Elective Course
SDG 7	Thermodynamics, Marine Engines, Ship Resistance, Marine Auxiliary Machinery, Ship Propulsion, Electrical Systems in Ships, Naval Architecture & Marine Eng. Design I, Naval Architecture & Marine Eng. Design II, Computational Fluid Mechanics, Technical Elective Course
SDG 8	Int. to Naval Arch. and Marine Eng. and Ethics, Entrepreneurship and Career Advising, Ship Theory, Ship Construction, Maritime and Labor Law, Work Safety & Health Training in Shipbuilding Industry, Naval Architecture & Marine Eng. Design I, Methods of Ship Production, Shipping Economics, Shipyard Organization, Ship Vibration, Naval Architecture & Marine Eng. Design II, Elective Internship, Technical Elective Course
SDG 9	Materials and Manufacturing Processes, Ship Design, Methods of Ship Production, Shipyard Organization, Elective Internship, Technical Elective Course
SDG 10	-
SDG 11	Ship Theory, Ship Motions and Maneuvering, Maritime and Labor Law Technical Elective Course
SDG 12	Dynamics, Materials and Manufacturing Processes, Fluid Mechanics, Thermodynamics, Marine Engines, Ship Resistance, Marine Auxiliary Machinery, Ship Propulsion, Ship Design, Electrical Systems in Ships, Naval Architecture & Marine Eng. Design I, Naval Architecture & Marine Eng. Design II, Computational Fluid Mechanics, Technical Elective Course
SDG 13	Marine Engines, Technical Elective Course
SDG 14	Technical Elective Course
SDG 15	Technical Elective Course
SDG 16	Int. to Naval Arch. and Marine Eng. and Ethics, Entrepreneurship and Career Advising, Maritime and Labor Law, Work Safety & Health Training in Shipbuilding Industry, Technical Elective Course
SDG 17	English for Academic Purposes, Essentials of Research Paper Writing, Technical Elective Course

Physics II Laboratory, Ship Geometry, Int. to Programming Language, Basics of Academic Writing, Entrepreneurship and Career Advising, Dynamics, Essentials of Research Paper Writing, Ship Theory, Ship Construction, Strength of Ships, Ship Design, Work Safety & Health Training in Shipbuilding Industry, Naval Architecture & Marine Eng. Design I, Naval Architecture & Marine Eng. Design II, Computational Fluid Mechanics, Elective Internship for ITU and Descriptive Geometry and Technical Geometry, Advanced English I, Ship Geometry, Basic Computer Science, Advanced English II, Mechanical Workshop, Mechanics, Computer Aided Design, Research Project, Elective Internship, Ship Design, Ship Structural Elements, Machine Elements, Ship Hydrostatics and Stability, Technical Elective Course, Ship Theory, Naval Architecture and Marine Eng. Lab, Ship Strength, Operation and Maintenance of Marine Machinery, Graduation Thesis for YTU. For the SDG5; Entrepreneurship and Career Advising, Work Safety & Health Training in Shipbuilding Industry have contribution in ITU curricula, however apart from the contribution of technical electives, no course has been identified at YTU. Marine Auxiliary Machinery is the only course supports SDG 6 in both. The SDG 7, affordable and clean energy, is an important goal in today's context where environmental issues are prominent. Contributions from both curricula in this area are provided through mutual courses such as Marine Auxiliary Engines (Marine Auxiliary Machinery in ITU) and Electrical Systems in Ships (Electrotechnique and Ship Electricity in YTU), as well as through additional courses like Thermodynamics, Marine Engines, Ship Resistance, Ship Propulsion, Naval Architecture & Marine Eng. Design I and II, and Computational Fluid Mechanics at ITU; and Ship Machinery I and II, Heat Transfer, Ship Resistance and Propulsion, and Graduation Thesis at YTU. For SDG

Table 7. The course breakdown structure of YTU regarding SDGs

SDGs	YTU- Naval Architecture and Marine Engineering Courses
SDG 1	Technical Elective Course
SDG 2	Technical Elective Course
SDG 3	Technical Elective Course, Occupational Health and Safety, Naval Architecture and Marine Eng. Lab
SDG 4	Descriptive Geometry and Technical Geometry, Advanced English I, Ship Geometry, Basic Computer Science, Advanced English II, Mechanical Workshop, Mechanics, Computer Aided Design, Research Project, Elective Internship, Ship Design, Ship Structural Elements, Machine Elements, Ship Hydrostatics and Stability, Technical Elective Course, Ship Theory, Naval Architecture and Marine Eng. Lab, Ship Strength, Operation and Maintenance of Marine Machinery, Graduation Thesis
SDG 5	Technical Elective Course, Occupational Health and Safety
SDG 6	Technical Elective Course, Marine Auxiliary Engines
SDG 7	Ship Machinery I, Heat Transfer, Technical Elective Course, Ship Machinery II, Ship Resistance and Propulsion, Marine Auxiliary Engines, Electrotechnique and Ship Electricity, Graduation Thesis
SDG 8	Int. to Naval Architecture and Marine Eng., Mechanical Workshop, Occupational Health and Safety, Technical Thermodynamics I, Technical Thermodynamics II, Research Project, Elective Internship, Ship Hydrostatics and Stability, Technical Elective Course, Ship Theory, Shipyard Management and Organization, Graduation Thesis
SDG 9	Mechanical Workshop, Material and Ship Building Materials, Elective Internship, Manufacturing Processes, Ship Design, Machine Elements, Technical Elective Course, Operation and Maintenance of Marine Machinery, Shipyard Management and Organization, Graduation Thesis
SDG 10	-
SDG 11	Occupational Health and Safety, Ship Hydrostatics and Stability, Technical Elective Course, Ship Movements, Ship Theory
SDG 12	Mechanics, Material and Ship Building Materials, Technical Thermodynamics I, Fluid Mechanics, Technical Thermodynamics II, Manufacturing Processes, Ship Design, Ship Machinery I, Heat Transfer, Technical Elective Course, Ship Machinery II, Marine Auxiliary Engines, Electrotechnique and Ship Electricity, Operation and Maintenance of Marine Machinery, Graduation Thesis
SDG 13	Ship Machinery I, Technical Elective Course, Ship Machinery II, Ship Resistance and Propulsion
SDG 14	Technical Elective Course
SDG 15	Technical Elective Course
SDG 16	Int. to Naval Architecture and Marine Eng., Technical Elective Course
SDG 17	Advanced English I, Advanced English II, English for Academic Purposes, Essentials of Research Paper Writing Technical Elective Course

8, Elective Internship holds a significant weight in both curricula. Additionally, courses such as Introduction to Naval Architecture and Marine Engineering, Ship Theory, and Shipyard Organization and Management may contribute to SDG 8 in both curricula. Additionally, in the ITU curriculum, courses such as Entrepreneurship and Career Advising, Ship Construction, Maritime and Labor Law, Work Safety & Health Training in Shipbuilding Industry, Naval Architecture & Marine Engineering Design I and II, Methods of Ship Production, and Shipping Economics contribute to this area. On the other hand, the YTU curriculum, contributions come from Mechanical Workshop, Technical Thermodynamics I and II, Research Project, Ship Hydrostatics and Stability, and Graduation Thesis. The engineering programs significantly have impact on ship building industry. As an SDG focusing on industry innovation and infrastructure, the SDG 9 finds a foothold from the lectures as Materials and Manufacturing Processes, Ship Design, Shipyard Organization, Elective Internship. Furthermore, Methods of Ship Production in ITU; Mechanical Workshop, Machine Elements, Operation and Maintenance of Marine Machinery, Graduation Thesis lectures in YTU have impact on the SDG. While naval architecture curricula have no contribution to the SDG 10, SDG 11 find support with the lectures as Occupational Health and Safety, Ship Hydrostatics and Stability, Ship Movements, Ship Theory. The lectures as; Dynamics (Mechanics), Materials and Manufacturing Processes, Fluid Mechanics, Thermodynamics (I and II), Marine Engines, Operation and Maintenance of Marine Machinery, Ship Resistance, Marine Auxiliary Engines, Ship Propulsion, Ship Design, Electrical Systems in Ships, Naval Architecture & Marine Eng. Design I, Naval Architecture & Marine Eng. Design II, Computational Fluid Mechanics, Heat Transfer, Graduation Thesis have relevancy with another significant

SDG, as responsible consumption and production SDG12. Marine Engines and Ship Machinery, Ship Resistance and Propulsion lessons have relevancy with SDG 13. SDG 14 and 15 are not supported noteworthy by curricula. SDG 16 has relevancy with the lessons Int. to Naval Arch. and Marine Eng. and Ethics, Entrepreneurship and Career Advising, Maritime and Labor Law, Work Safety & Health Training in Shipbuilding Industry and SDG 17 has relevancy with English for Academic Purposes, Essentials of Research Paper Writing courses.

3.3. Mutual Aspect Between IMO Topics and SDGs

Table 8 presents the IMO Agenda for the years 2020-2022 and the topics discussed by the sub-committees. This Agenda outlines the areas of focus for the IMO, emphasizing that naval architecture and marine engineering education should be consistent with these focus areas. The topics are linked to relevant SDGs to assess the alignment of ITU and YTU's naval architecture and marine engineering curricula. It appears that the ITU and YTU curricula primarily contribute to the topics of IMO 2, IMO 4, IMO 5, IMO 6, and IMO 8. The "Human element, training and watchkeeping (IMO 5)" topic is mainly supported by courses related to SDG 4 and SDG 8 within the ITU and YTU curricula. 51% of the ITU curriculum's courses and 49% of the YTU curriculum's courses correspond to this topic. "Implementation of IMO Instruments (IMO 8)" is another IMO topic effectively covered by the ITU and YTU curricula. Courses related to SDG 4 and SDG 16 provide the main contribution to the IMO 8 topic. 45% of the ITU curriculum and 41% of the YTU curriculum consist of courses related to this topic. The ITU and YTU curricula adequately meet the requirements of the IMO 2 and IMO 6 topics. 45% of the courses in the YTU curriculum are related to the "Ship design and construction (IMO 2)" topic, and 39% of the courses in the ITU curriculum are as well. The "Carriage of cargoes and containers (IMO 6)" topic is covered by 33% of the courses in the ITU curriculum and 31% of the courses in the YTU curriculum. Courses under SDG 2 provide the main support to the IMO 2 topic, while courses under SDG 8 make the primary contribution to the IMO 6 topic. Another IMO topic to which both curricula make a significant contribution is "Ship systems and equipment (IMO 4)". The courses most relevant to this topic are categorized under SDG 12, and 41% of the YTU curriculum and 37% of the ITU curriculum consist of courses that cover this topic. When the ITU and YTU curricula are evaluated with respect to other IMO topics, SDG 9 courses provide the main contribution to the "Safety of navigation, communication, and search and rescue (IMO 1)" topic, SDG 12 courses effectively cover "Pollution prevention and response (IMO 3)", and SDG 7 courses are directly related to "Reduction of greenhouse gas emissions from ships (IMO 7)".

Table 8. The relation between IMO Topics and SDGs.

IMO Topics	SDG-related	
	Directly	Partly
IMO 1- Safety of navigation, communication and search and rescue	11, 14	9, 17
IMO 2- Ship design and construction	9, 12, 13	14, 17
IMO 3- Pollution prevention and response	6, 12, 13, 14	15, 17
IMO 4- Ship systems and equipment	9, 12	3
IMO 5- Human element, training and watchkeeping	3, 4	8, 17
IMO 6- Carriage of cargoes and containers	8, 14	13, 17
IMO 7- Reduction of greenhouse gas emissions from ships	7, 13, 14	6, 15
IMO 8- Implementation of IMO instruments	16, 17	4

It must be also mentioned that another crucial organization the International Towing Tank Conference (ITTC) which is recognized as an NGO with observer status to IMO. The ITTC serves as a global reference point in the performance analysis of naval architecture and marine structures. It addresses numerous topics covered within the naval engineering curriculum, either directly or indirectly. However, it does not directly shape education or provide curriculum recommendations. The recommended procedures and guidelines contribute to setting standards within the maritime industry. The Executive Committee oversees the daily operations of the ITTC and reports its findings, on technical matters relevant to the sector. The topics covered by the technical committees include topics about ship resistance and propulsion conducting test procedures and calculations, such as resistance tests, various propulsion tests, cavitation analyses, hydrodynamic noise and energy saving methods thereby supporting SDG 9, SDG12 and SDG13. Additionally, it contributes to SDG 14 (Life Below Water) through its procedures for noise measurements. The procedures about maneuvering, maneuvering in waves, ships operations at sea, stability, stability in waves covered by the technical committees of Maneuvering Committee, Seakeeping Committee and Stability in Waves committee covers SDG 11 and SDG 14. Among the topics addressed by ITTC are speed and power trials necessary for calculating the Energy Efficiency Design Index as mandated by the IMO. Its contributions to environmental sustainability, efficiency, and high-quality instrumentation are undeniable, establishing a direct connection to SDG 12 and SDG 9. ITTC's contribution to SDG 8 is reflected in its support for the shipbuilding industry, ship operators, and designers, provided by its professional team. By including procedures for offshore wind turbines and wave energy structures, in Ocean Engineering committee, ITTC supports SDG 7, SDG 9, SDG 11 SDG 12 and SDG 13, significantly. Lastly, ITTC's Executive Committee maintains communication with organizations such as IMO, as highlighted in the article, thereby aligning with SDG 17.

3.4. Annual Based Analysis of Curricula Regarding SDGs

Considering year-based analysis, the alignment with SDGs varies as each course is introduced in different semesters/years. The Figure 3 demonstrates the a) ITU and b) YTU distribution of curricula's annual based contribution. The figure is designed considering four year and the X-axis shows the end of the year.

As an outcome of this analysis, ITU's first year indicates the highest emphasis on SDG 4 (Quality Education), with receiving a 57% of priority for the first year, considering the amount of SDG support of courses throughout the year. SDG 8 (Decent work and economic growth) and SDG 16 (Peace, Justice and strong intuitions) are in 2nd and 3rd place with 14% both. For YTU, SDG 4 is also in the first place by 50% and followed by SDG 8 and SDG 17(Partnerships for the goals) with 17% contribution.

For the second-year assessment, ITU's curriculum has the most courses oriented towards SDG 12 (Responsible consumption and production), the rate makes it the top priority with 44%. SDG 4 is in 2nd place for the year with 22%. Additionally, SDG 7, SDG 9, SDG 17 have the same share for supported by 11% of the courses. For YTU's 2nd year evaluation, SDG 12 is again the top priority. Despite SDG 4 and SDG 8 being in second place, there is a significant proximity with SDG 9 (Industry, innovation and infrastructure) in the curriculum, with relevance levels of 28%, 20%, and 16% for both, respectively.

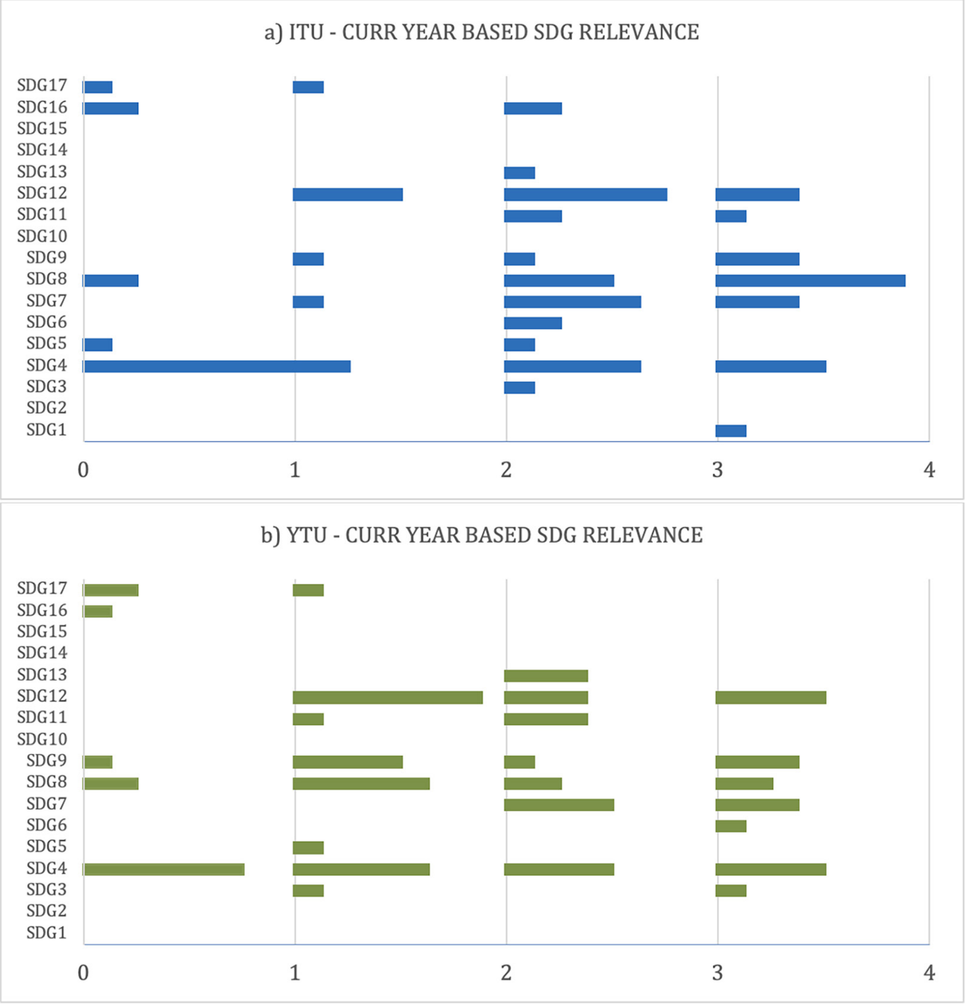

Figure 3. Year based analysis of ITU (a) and YTU (a) curriculum.

ITU: Istanbul Technical University, YTU: Yıldız Technical University

In the third year, with the increase in vocational courses, there is a broader distribution. In ITU's curriculum, SDG 12, SDG 7 (Affordable and clean energy), SDG 4, and SDG 8 are prioritized with relevance levels of 20%, 17%, 17%, and 13%, respectively. On the other hand, in YTU's third year, SDG 7 and SDG 4 are supported by 20% of the courses, while SDG 11 (Sustainable cities and communities), SDG 12, and SDG 13 (Climate action) are supported at 15% level.

In the fourth year, ITU's curriculum stands out for its association with SDG 8, with a relevance level 32% of the courses and followed by SDG 4 18%, SDG 7, SDG 9, and SDG 12 with 14% support level. For YTU's curriculum, SDG 4 and SDG 12 are prominent, with a relevance level of 22%. SDG is at the fifth order with 11% after the SDG7 and SDG9 17% both support by courses.

3.5. Overall Assessment of Curricula with SDGs

This section will analyze the collective contributions of the curricula as consecutive process of the year-based assessments. The comprehensive evaluation of the curriculum allows for a clear identification of its strengths and weaknesses by analyzing the extent to which the courses a student will take over the four-year education period contribute to the SDGs. Figure 4 presents a comparative analysis for both ITU and YTU, showing the percentage of courses within each curriculum that contribute to the relevant SDGs.

In evaluating both curricula within the scope of the SDGs, the most notable aspect is their contribution to SDG 4 (Quality Education). This is an expected outcome, as education has been emphasized as a priority in the context of sustainability goals, even in the MDGs. SDG 4 receives the highest level of support in the both curricula, with 40% of the courses in the ITU curriculum and 39% in the YTU curriculum contributing to this goal. These percentages indicate that 20 courses within the naval architecture and marine engineering programs contribute to this goal during a student's education. Additionally, another SDG that both curricula strongly support is SDG 12 (Responsible Consumption and Production), with 28% and 29% of the courses in ITU and YTU curricula, respectively contributing to this goal.

Figure 4. Program comparison of the two universities with respect to SDGs.

In the third position among the SDGs supported by the curricula, SDG 8 (Decent Work and Economic Growth) is again observed in both curricula. SDG 8 is supported by 28% at ITU and 24% at YTU. A divergence is observed in the fourth most supported SDGs. While the ITU curriculum supports SDG 7 (Affordable and Clean Energy) at a rate of 20%, the YTU curriculum supports SDG 9 (Industry, Innovation, and Infrastructure) at the same rate. In the fifth position, SDG 7 is supported by 16% at YTU, while SDG 9 is supported by 12% at ITU, reversing the positions seen in the previous fourth order. As the ranking decreases, there is a significant decline and differentiation in the level of support. For instance, SDG 16 (Peace, Justice, and Strong Institutions) is supported by 10% in the ITU curriculum, ranking sixth, whereas it is supported by 4% in the YTU curriculum, ranking tenth. Conversely, SDG 11 (Sustainable Cities and Communities) is supported by 10% in the YTU curriculum, ranking sixth, while it is supported by 8% in the ITU curriculum, ranking tenth. In the seventh position, both curricula support SDG 17 (Partnerships for the Goals), with ITU providing 6% support and YTU 8%. Additionally, in the seventh position, the ITU curriculum also supports SDG 5 (Gender Equality) and SDG 6 (Clean Water and Sanitation), while the YTU curriculum ranks SDG 13 (Climate Action) as seventh. As for the least supported SDGs, in the ITU curriculum, SDG 1 (No Poverty) and SDG 13 (Climate Action) are supported at 4%, ranking tenth. SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), SDG 14 (Life Below Water), and SDG 15 (Life on Land) are the least supported, with a support rate of 2%. In the YTU curriculum, SDG 3 (Good Health and Well-being) is ranked ninth with 6% support, while SDG 6 (Clean Water and Sanitation) is ranked tenth. The least supported SDGs in the YTU curriculum, with 2% support, are SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 5 (Gender Equality), SDG 14 (Life Below Water), and SDG 15 (Life on Land). Overall, it is notable that the least supported SDGs are common in both curricula.

Although some SDGs are directly related to the naval architecture industry, their integration into the curriculum appears to be weak. These include SDG 3, SDG 13, and SDG 14. A reason for this outcome is that these SDGs are more often included as topics in elective courses. For instance, SDG 14 involves marine biology, which is not a compulsory course in the curricula of Naval Architecture and Marine Engineering. Additionally, its limited coverage within mandatory courses contributes to this result. Introducing a course addressing ship recycling and its environmental impacts or a course examining the environmental dimensions of port management could support this SDG. Similarly, SDG 13 is another underrepresented SDG. This gap might stem from the limited coverage of machinery-related courses. Including the topic of "energy management" in courses on ship production or shipyard management could enhance contributions to this area. SDG 3 also holds significant importance for the shipbuilding industry. However, its weak connection is likely due to its limited integration into mandatory courses. Furthermore, having a course exclusively dedicated to this topic, while increasing focus, may have adversely impacted its distribution across the curriculum. It is essential to remember that habits and skills are not developed instantaneously. As the proverb says, "Slow and steady wins the race".

The study was prepared by reviewing the course catalogues. It may vary to some extent depending on practical/physical opportunities of universities and the experience of the instructors. However, the course catalogues reliably referenced in this study, which serve as a central tool for the European Credit Transfer and Accumulation System (ECTS), aim to enhance transparency in studies and courses and make national education systems more internationally comparable. The ECTS also supports the evaluation, planning, and delivery of HE programs, representing learning based on clearly defined learning outcomes. The use of ECTS systems in the accredited educational institutions has enabled a bottom-up methodology for evaluating the overall educational curriculum within the framework of the SDGs. This evaluation, based on weekly plans in course catalogues, is limited to the curriculum itself. To assess the competencies acquired by engineers, GAs, detailed course evaluation surveys, including thoroughly analyzed student grades, are required. However, this would constitute the further study of this long-term and comprehensive research.

4. Conclusion

Universities are among the most significant actors in the development of new technologies and the transmission of existing knowledge and experience to future generations. Considering the urgency of the SDGs, and the challenges and needs of the era, it is essential for universities worldwide to integrate the concept of sustainable development into the curricula, particularly in the education of engineers who consider economic, environmental, and social responsibilities through their work, as well as in other disciplines.

The study focuses on the relevancy of SDG with naval architecture curriculum and aims to reveal strengths and weaknesses regarding SDGs. The strengths within the curricula are identified as SDG 4 (Quality Education), SDG 12 (Responsible Consumption and Production), SDG 8 (Decent Work and Economic Growth), SDG 7 (Affordable and Clean Energy), and SDG 9 (Industry, Innovation, and Infrastructure). On the other hand, SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land) have been identified as the weakly supported SDGs of the naval architecture and marine engineering curricula. The results may vary according to disciplines of the curricula, and their content. In order to leverage the relevancy with SDGs, the proposal of elective courses regarding SDGs may be incentivized for instructors. The curricula have compulsory courses, and the weekly course plan of the courses may be reconsidered with SDG perspective, and efforts to encourage students not only to increase their awareness but to internalize the concept of sustainability through education will facilitate the acceleration of this transition process. It should also be emphasized that as the need for sustainable development continues to grow in line with the demands of the era, the responsibility of universities will likewise continue to increase.

Footnotes

Authorship Contributions

Concept/Design: Ç. Dere, and S. Bulut, Data Collection or Processing: Ç. Dere, and S. Bulut, Analysis or Interpretation: Ç. Dere, and S. Bulut, Literature Review: Ç. Dere, and S. Bulut, Writing, Reviewing and Editing: Ç. Dere, and S. Bulut.

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